DECEMBER 1959

JOURNAL OF THE IRON AND STEEL INSTITUTE

4 GROSVENOR GARDENS LONDON SW1

Established 1869 Incorporated by Royal Charter 1899

VOLUME 193 PART 4

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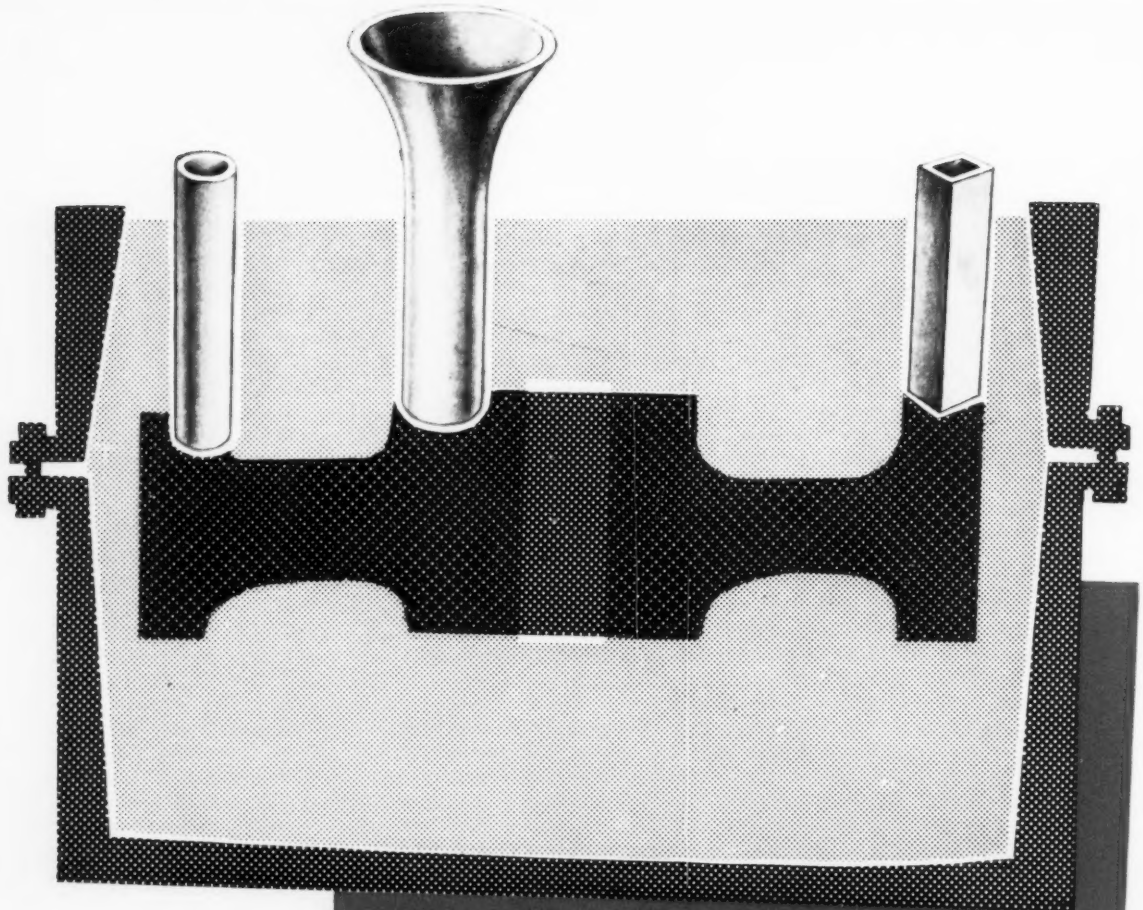

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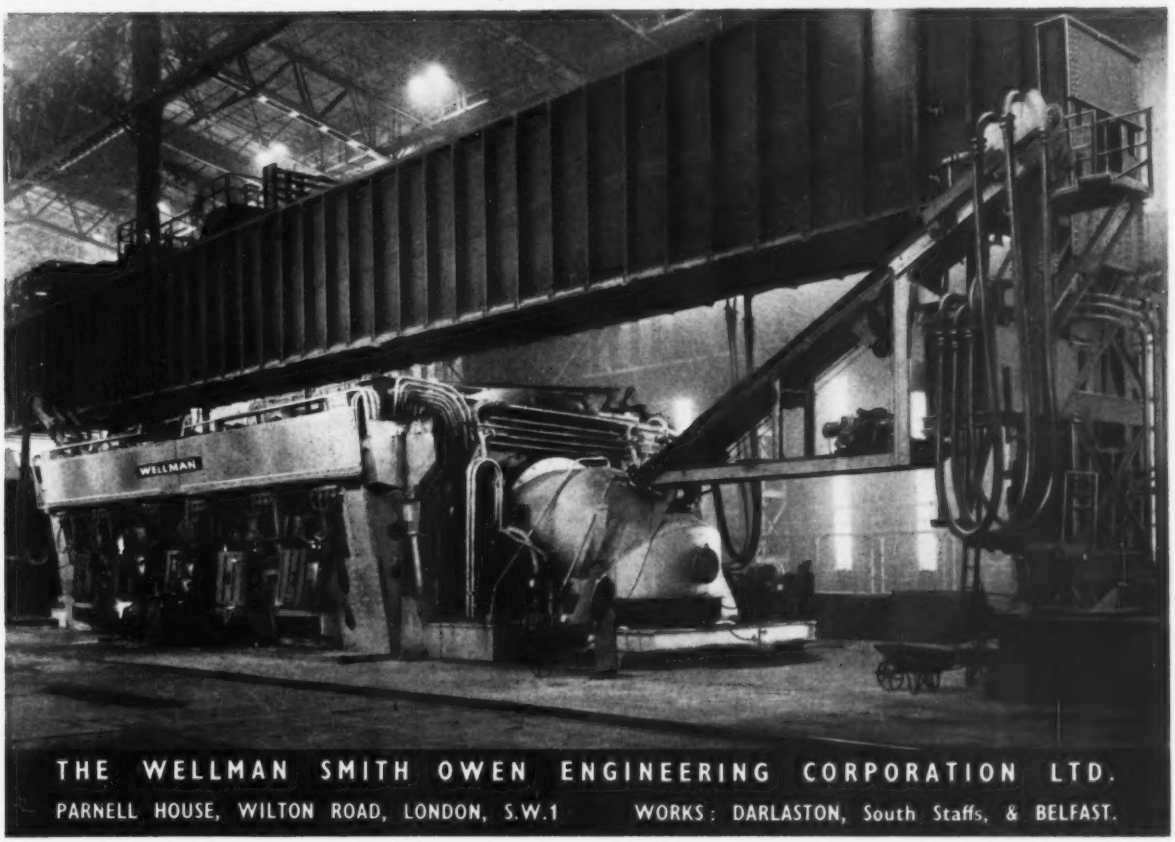

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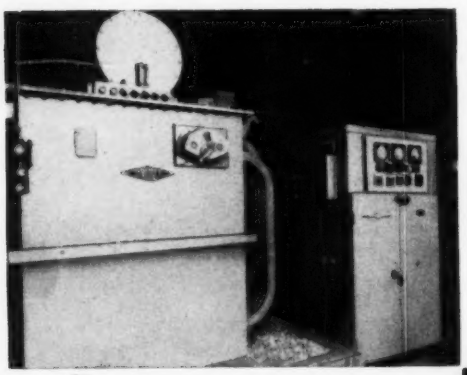
An irrigated Holmes-Elex Electrical Precipitator preceded by a gas storage/wash tower cleaning exhaust air from the deseaming plant at the Rotherham Works of Messrs. Steel Peech & Tozer (Branch of the United Steel Companies Limited). The photograph inset shows the exhaust hood enclosing the deseaming plant



The first electrical precipitator to operate on deseaming plant in the U.K. was installed by our Gas Cleaning Division at the Corby Works of Messrs. Stewarts & Lloyds Ltd. in 1954. A further installation was recently commissioned at the Bilston Works of the same company.

E C C

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All electrical equipment used in conjunction with Holmes-Elex Electrical Precipitators is supplied by The Electric Construction Company Limited.

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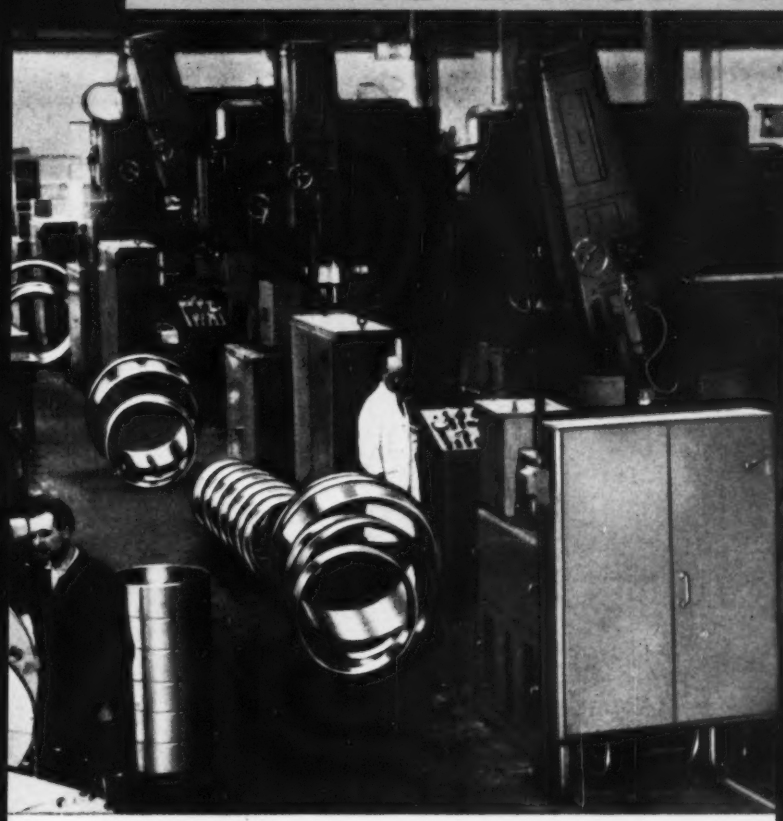

THIS battery of Bullard high-precision grinders, the only one of its kind in this country, is installed at our Daventry factory which concentrates solely on the manufacture of large Timken bearings.

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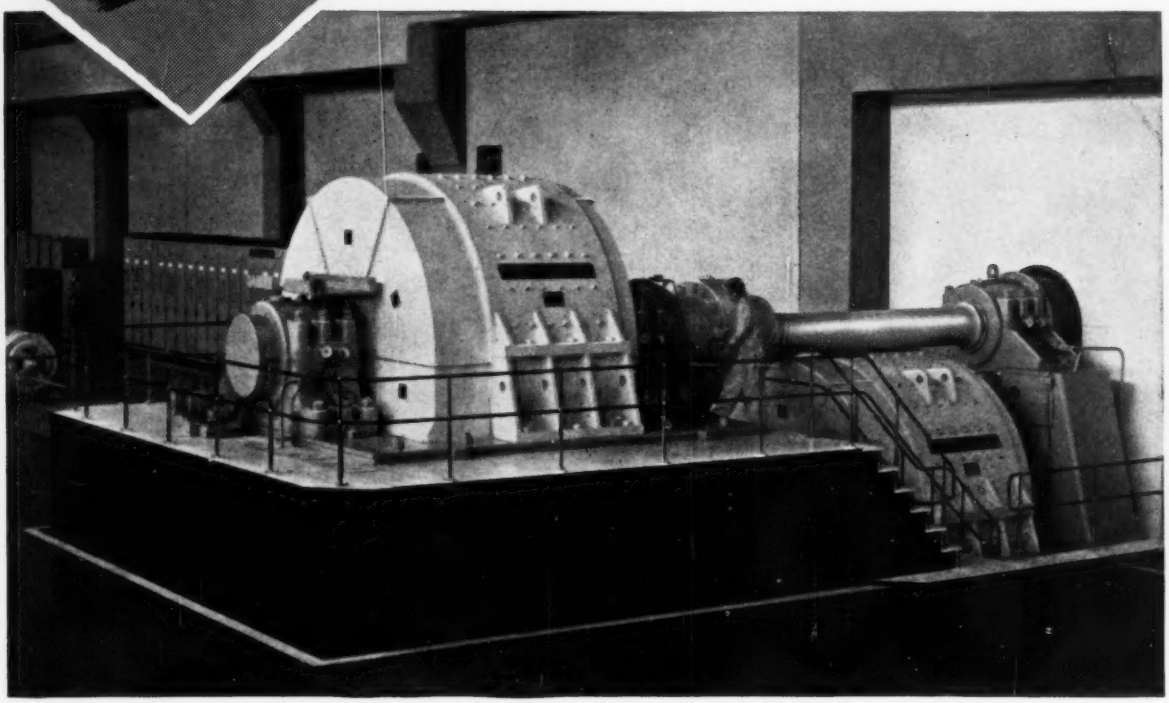

Under a comprehensive contract for the complete electrification of the new integrated steelworks of Empresa Nacional Siderurgica, 'ENGLISH ELECTRIC' supplied the first twin-drive in Spain.

This drive is for a 42" hot reversing blooming mill and is rated at 7,000 h.p. (r.m.s.) with a speed range of 50/120 r.p.m.

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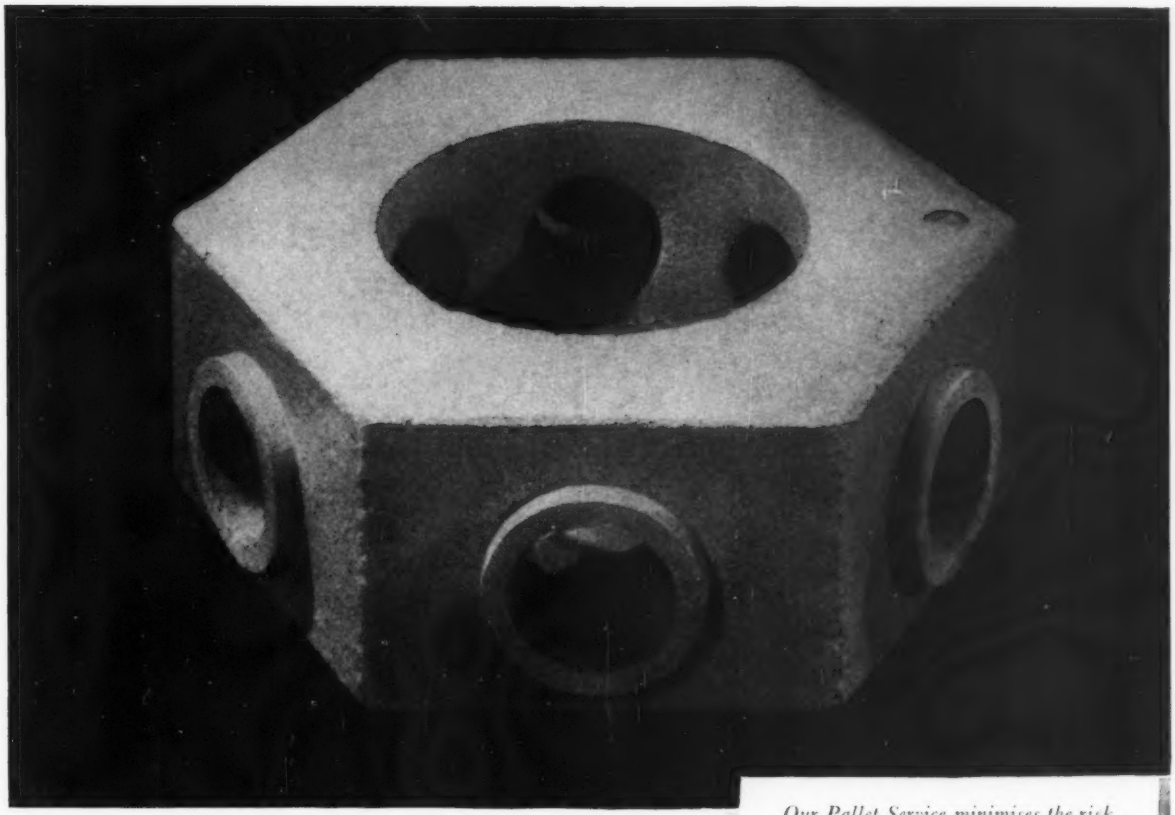

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Illustration shows a 15″ and 37″ × 60″ Reversing Four-high Cold Rolling Mill for soft, and alloy steel strip up to 50″ wide. Maximum rolling speed 1,200 ft./min.

Photograph by courtesy of Messrs. Richard Thomas & Baldwins Ltd.

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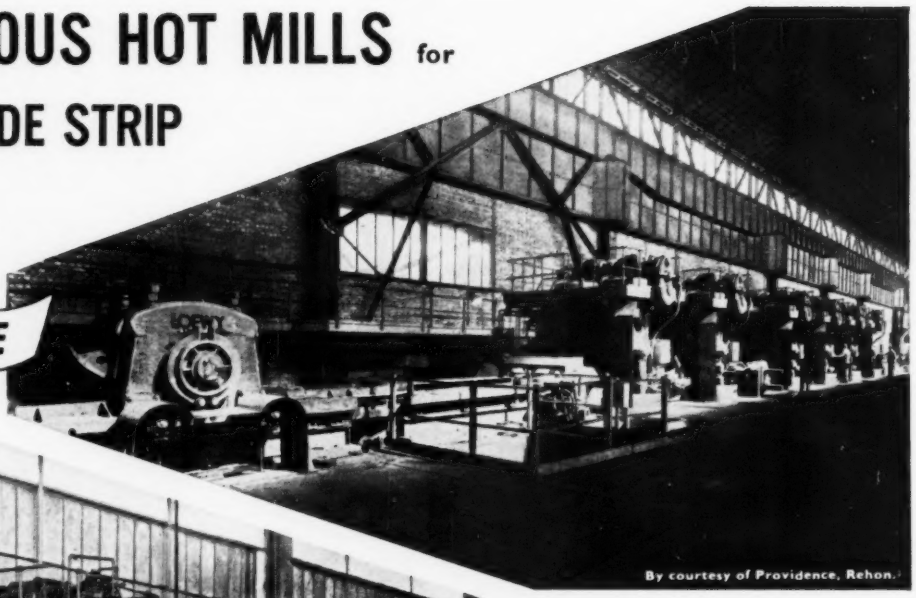

By courtesy of Providence, Rehon.

ITALY

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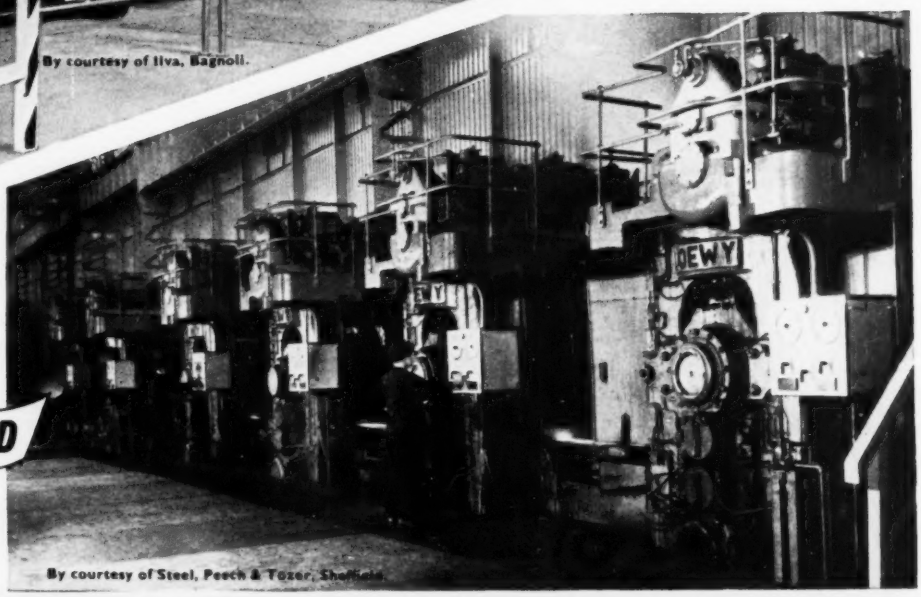

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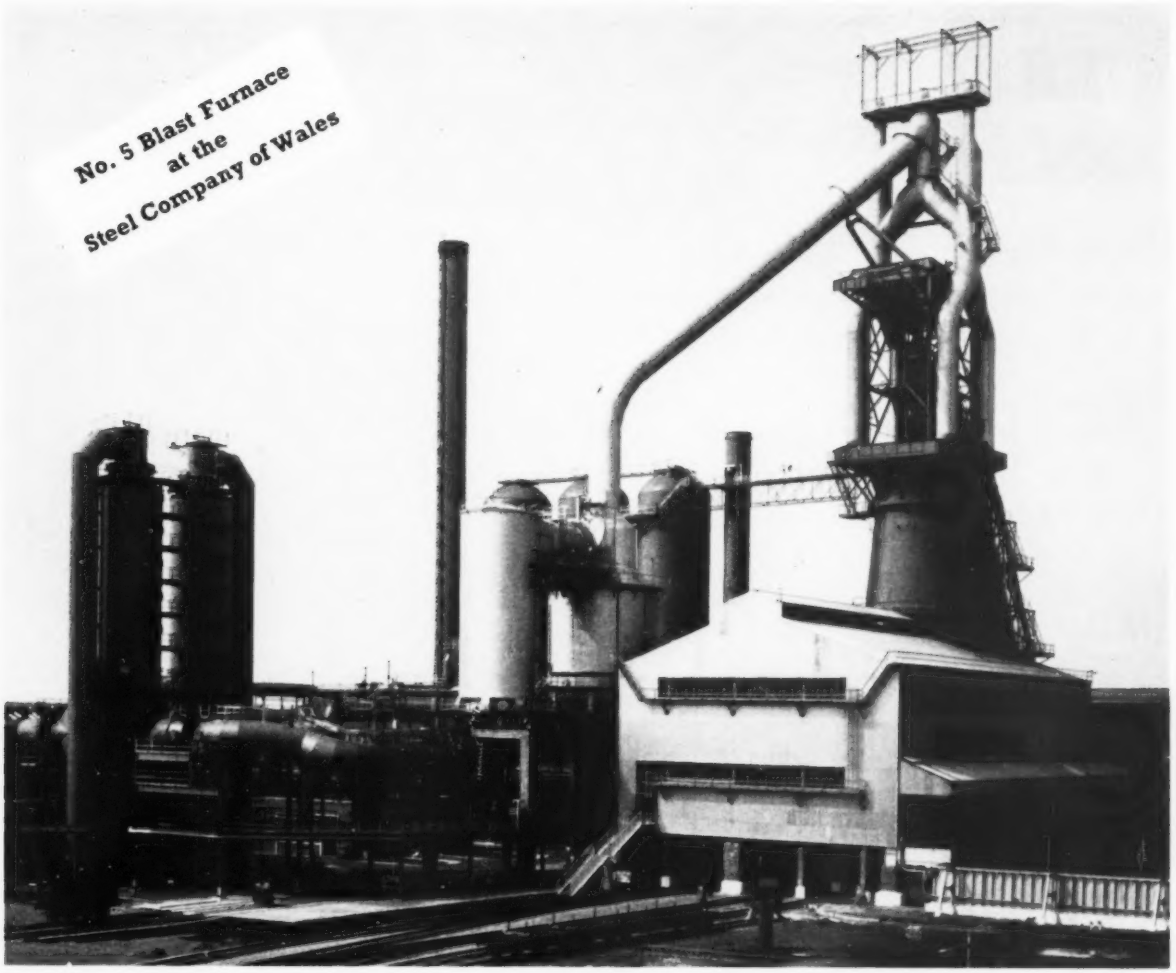

Photo courtesy Steel Co. of Wales

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This portable auxiliary unit, designed specifically for use with KELVIN HUGHES Flaw Detectors, provides automatic monitoring facilities which hitherto were obtainable only with larger, more expensive equipment. Significant defects are identified automatically and are indicated by warning lights and alarm devices.

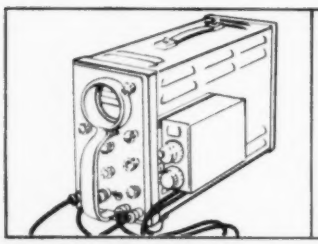
PRINCIPAL ADVANTAGES:

• Removes the onus of signal discrimination from the operator • Reduces operator fatigue • Reduces inspection time • Reduces inspection costs

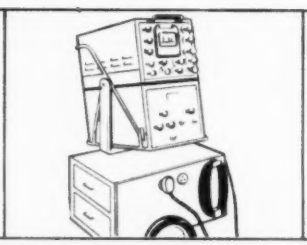
TECHNICAL FACILITIES:

• Simultaneous examination of two independent regions in the material • Automatic indication of the presence of flaws within these regions • Independent adjustment of the depth of each region under inspection • Independent adjustment of the position of each region • Independent adjustment of the sensitivity within each region.

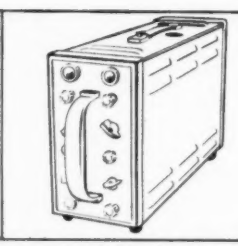
The Flaw Alarm Unit weighs only 20 lb. (9.1 kg.) and the Flaw Detector only 28 lb. (12.7 kg.), thus a completely semi-automatic inspection equipment, which can easily be carried by a single operator, is now available.



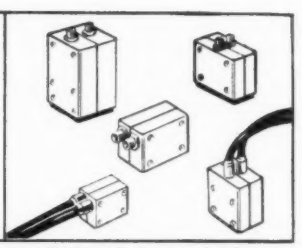
Flaw Detectors, Marks 5F, 5AF. *Portable instruments with similar basic specifications. The 5F is a multi-frequency instrument for use with twin or separate type probes, whilst the 5AF, a single frequency instrument, either 1½, 2½ or 5 Mc/s. Also operates with single type probes. (Shown with Depth Gauge attachment).*



Flaw Detector Mark 6. *Trolley mounted transportable equipment, very powerful and versatile for use with all types of probes and having an exceptionally wide frequency range and high sensitivity.*



Two-Channel Flaw Alarm. *For use with Mark 5 instruments, a portable auxiliary unit providing semi-automatic monitoring facilities which identify and give warning of significant defects.*



Probes. *Extensive development by Kelvin Hughes has resulted in a range of standard probes having either single, twin or separate transducers, and a very high performance throughout.*

AUXILIARY EQUIPMENT

Includes a Depth Gauge for use with all instruments and which will measure thicknesses between 0.1 to 4 ins. with high accuracy. Probe Holders with irrigation facilities for large surface scanning, and remote Probe Manipulators.

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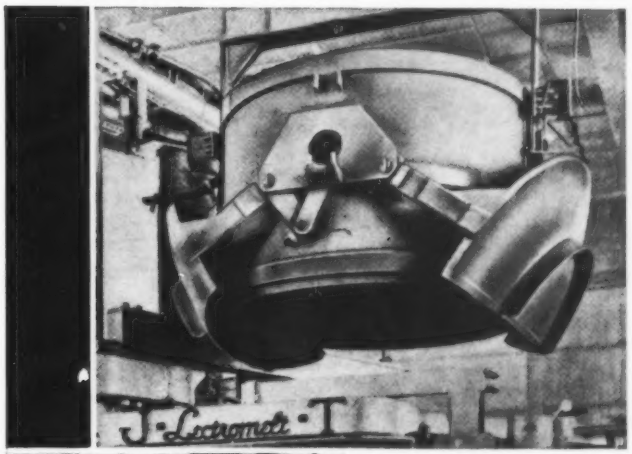

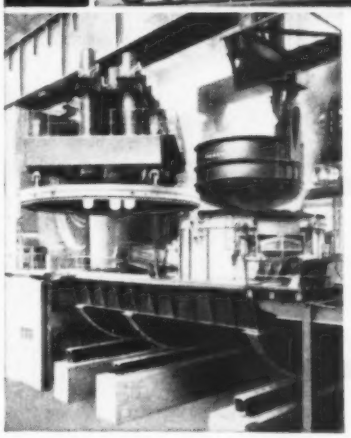

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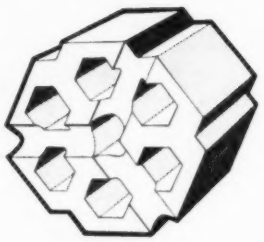

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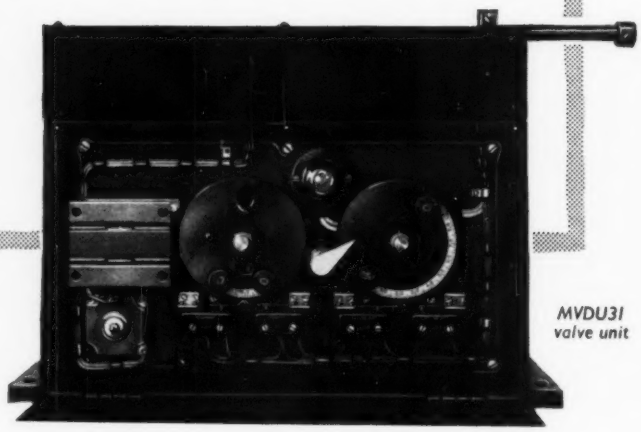

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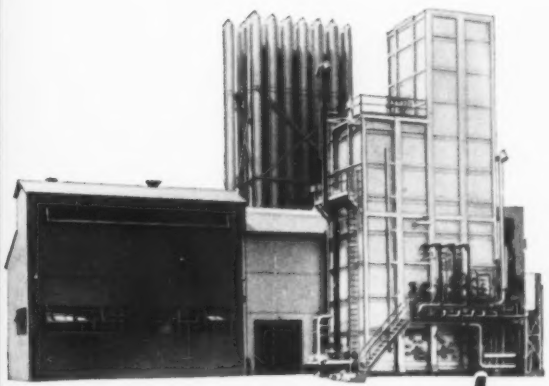

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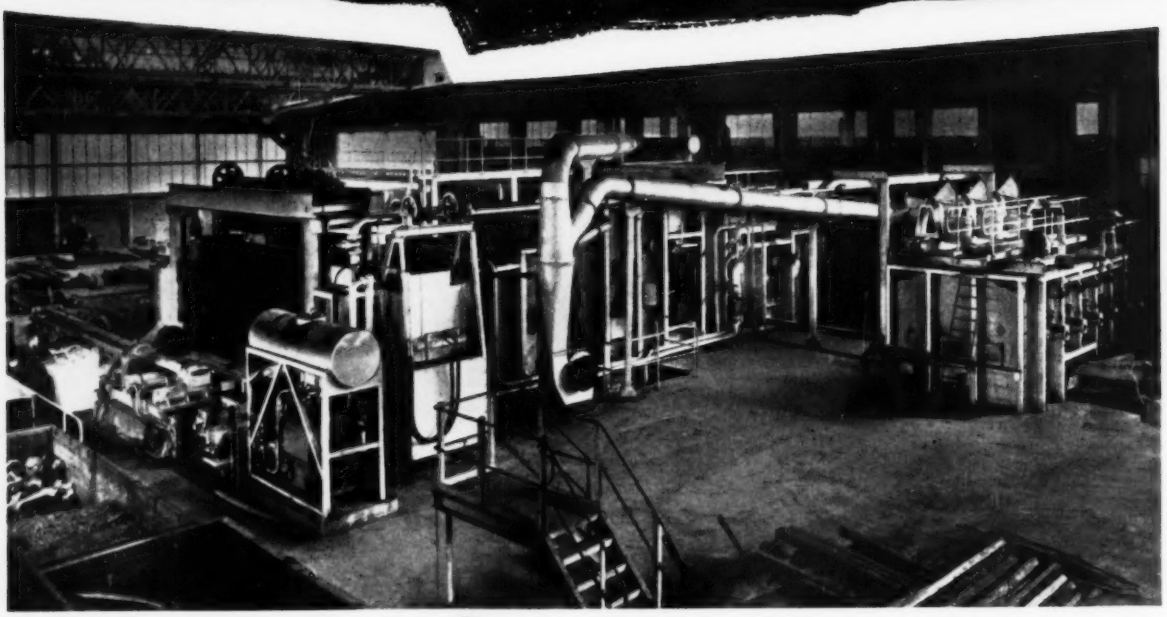

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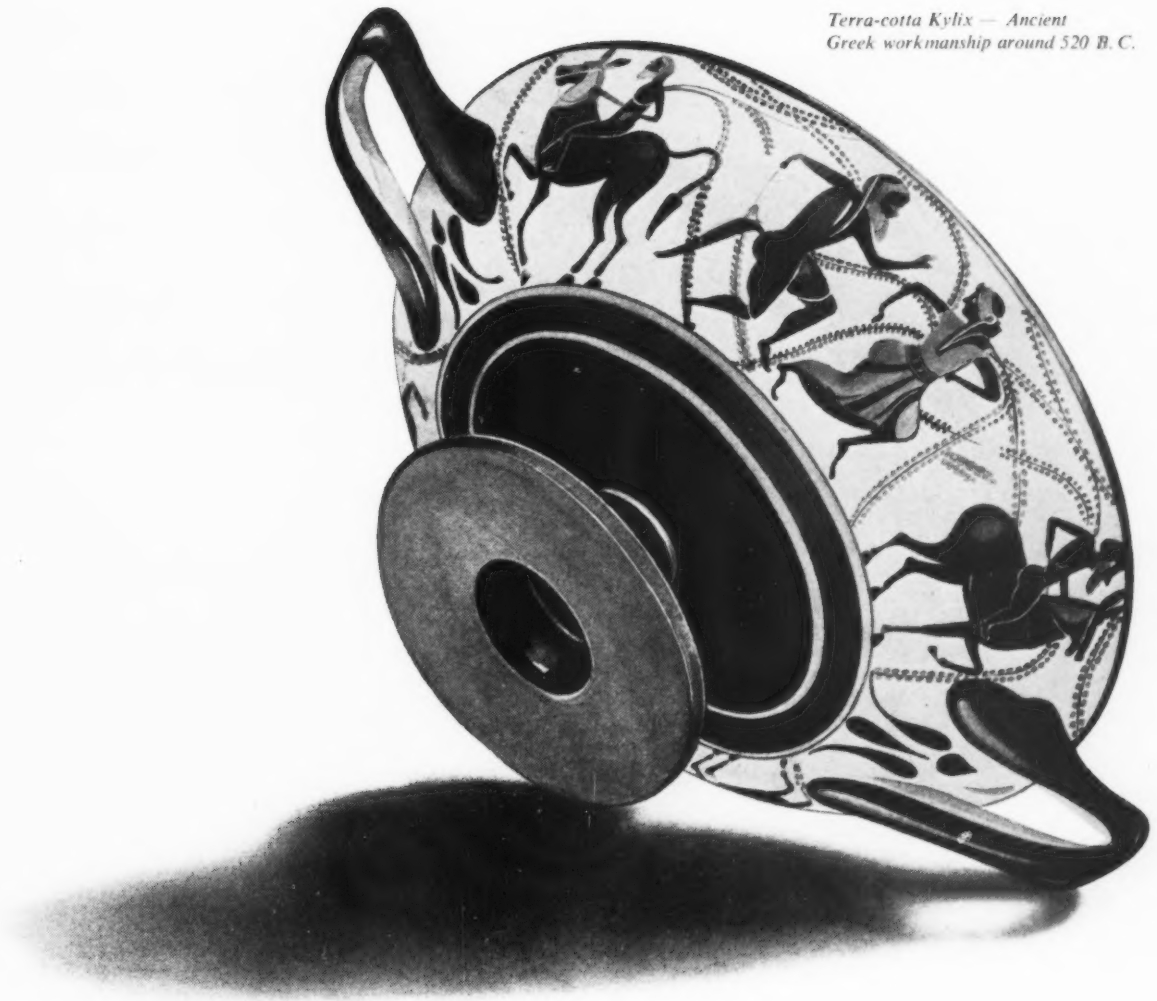

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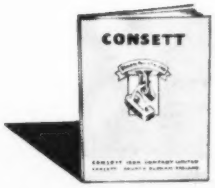

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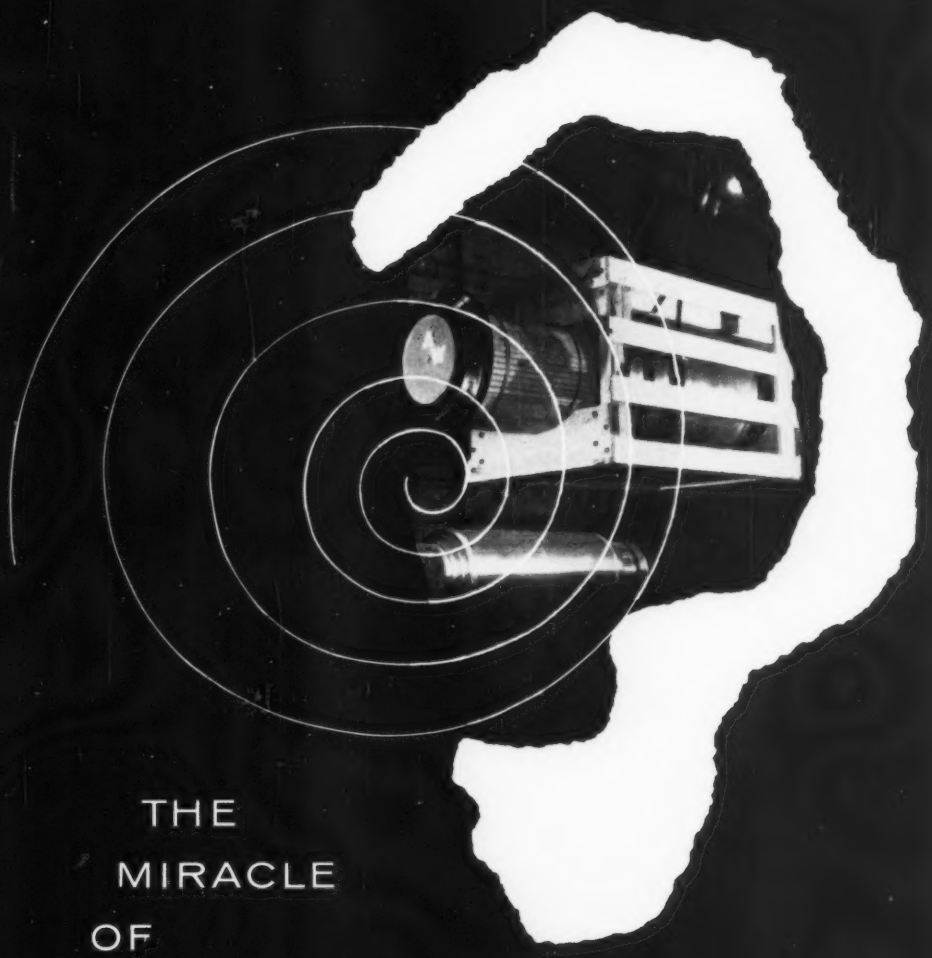

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Ultrasonics—sound waves so short that they are lost forever to the human ear.
Yet they have their uses. At 'A.W.' for example they help to guarantee that Rolls are absolutely free from internal ruptures, cavities or other defects prejudicial to perfection.
These very high frequency waves are sent through each Roll and the time of their reflected return is measured electronically. Should the waves encounter even the smallest crack or cavity they will be reflected prematurely and pin-point any flaw with accuracy.

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Armstrong Whitworth (Metal Industries) Ltd,
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Subsidiary Company:
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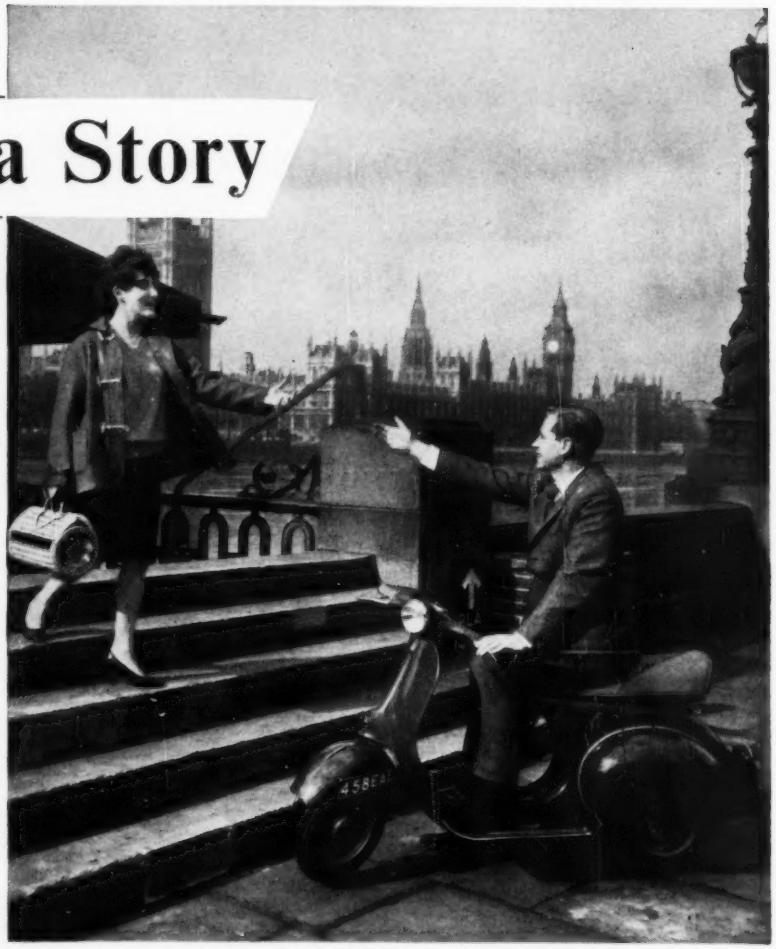
Western Road, Co. Durham

The Vespa Story



"Out of darkness cometh light"

Post-war Italy was bankrupt—physically, politically and economically it was a scene of desolation. Yet it was in this unprepossessing economic environment that Dr. Piaggio in Genoa started an enterprise which has revolutionised post-war personal travel throughout the world. Within twelve months of Mussolini's mutilation, he had produced over two thousand of the now world-famous Vespa Motor Scooters. Within ten years he was to make a million. Now, the Italian Vespa Company employs more than 4,000 workpeople and the robust little Vespa has completely democratised personal transport. Workmen in factories, doctors on their rounds, bankers, stockbrokers and film stars in every country are all proud Vespa owners. In fact, the Vespa has eradicated motor car snobbery and made tens of thousands of womenfolk motorists for the first time.

At home, pre-war, the name of Douglas was famous in the motor cycle world, but in the immediate post-war years this famous Douglas Company at Bristol had fallen on evil times. It was in the hands of the receiver when Claude McCormack, a Coventry Motor Engineer, took over what seemed an insuperable task of rehabilitation. By chance, whilst holidaying in Italy, he saw the Vespa, and although in charge of a bankrupt firm he nevertheless persuaded the then well-established Italian Vespa Company to grant manufacturing rights to Douglas. The Vespa brought success to the bankrupt Douglas organisation; the jobs of more than a thousand people were saved; bank overdrafts were repaid; shareholders realised unhoped-for prices for shares worth previously only a few coppers, and the Douglas Company became worthy of purchase by the powerful Westinghouse Brake and Signal Company Ltd. Thus the birth of the British Vespa took place also in an environment of economic desolation. Now the Douglas Company at Bristol employs nearly 2,000 people and the output of Douglas Vespas has topped the 100,000 mark. Quite recently the 'Financial Times' reported that the domination of the United Kingdom scooter market by imported European models looks like ending. United Kingdom production has increased 100% in the past twelve months and imports only a quarter, whilst British exports to the United States, the Commonwealth and Scandinavia are expanding. If any proof is required that trials and tribulations inspire mankind to prodigious effort, surely the Vespa story is a pertinent example.

At Kingswood there is a modern Vespa production line modelled on the motor car industry. Large presses stamp out the framework and overhead conveyors take the chassis and components to the paint and assembly shops.

However, the Vespa's attractive colour coat serves as a protective mantle to the robust and reliable power, transmission and braking systems which lie beneath. The construction of the components for these systems presents many problems for the metallurgist. Most of them depend upon heat treatment, carburising, tempering, etc., which demand very close time/temperature

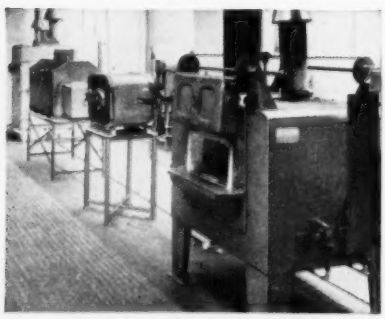


Fig. 2. A view of the new industrial gas showroom opened by the South Western Gas Board.

schedules. For this reason most of the furnaces are on automatic temperature control where thermocouples measure the temperature and transmit an electrical signal to control pyrometers which operate valves in the gas supply according to the measured temperature. This ensures that the temperature never varies from the close limits necessary for correct heat treatment which largely determines the life of the components. The Douglas Company uses town gas supplied by the South Western Gas Board for melting, hardening, tempering and carburising as well as stoving the synthetic paint finishes. For these purposes town gas is the most suitable fuel because its declared calorific value lends it well to precise automatic control. Other advantages are, of course, that there are no interruptions for fuel deliveries, and the gas meter provides the simplest and cheapest form of fluid fuel costing.

In the foundry gas is used for core drying, and aluminium alloy melting is carried out in three gas-fired melting furnaces, the molten metal being used for the gravity die-casting of the light alloy components. Crankshafts, gears, etc. require special heat treatment to fit them for their arduous life, and in the Carburising Shop there are three gas-fired muffle furnaces as well as a high-speed tempering furnace. Other non-ferrous components are treated in gas-fired salt bath furnaces.

The standard of finish on the Douglas Vespa is extremely high. The chassis, mudguards, etc. having been assembled, stress-relieved and filled, pass on conveyors into the finishing shop. After being sprayed with a number of priming and finishing coats of paint the components pass, still on conveyors, into a gas-fired infra-red paint stoving oven which was specially designed to suit the awkward shape of the chassis, thereby ensuring that each part of the painted surface received adequate heat. Again town gas was chosen as the fuel because it lends itself more easily to the close time/temperature schedules required to cure the modern synthetic paints.

Undoubtedly the large output of Vespa Scooters has benefited from the close co-operation between the South Western Gas Board, the equipment suppliers and the Douglas Company. As part of its service to industrialists in the South West the South Western Gas Board has recently opened an Industrial Gas Showroom where factory executives can inspect working examples of infra-red tunnels, natural draught oven furnaces, muffle furnaces, recirculating ovens, etc. Anyone can bring along the components in which they are interested and try them out with the equipment in advance of purchase. A small pottery kiln is in great demand by schools in the district, and examples of decorated and glazed pottery reflect high credit not only upon the schoolboys and girls but upon the precise time/temperature schedules obtainable with town gas in a relatively inexpensive kiln. In addition, there is a wide range of gas burners together with ancillary equipment such as flame protection and ignition systems where automatic temperature control figures prominently.

This Industrial Gas Showroom is one positive example whereby the Gas Industry through its Industrial Gas Officers at the Area Gas Boards is serving industry—these officers from all over the United Kingdom meet regularly to discuss developments, so that any manufacturer approaching any Area Gas Board has at his disposal the pooled knowledge throughout the country in some 4,000 different trades and industries served by gas. One practical result of this service is reflected in the Douglas plant at Kingswood, Bristol —and the name of Douglas is in turn reflected in the ever-increasing market for its ever popular and glamorous Vespa Scooter.

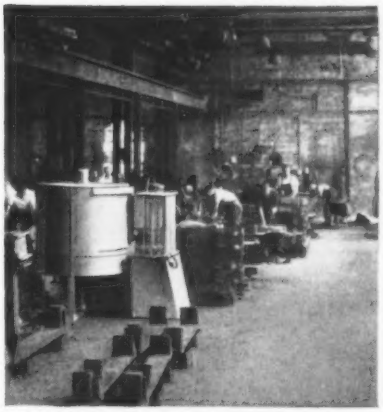


Fig. 4. A view of the gas-heated core drying installation in the foundry of Douglas Engineering (Kingswood) Ltd.

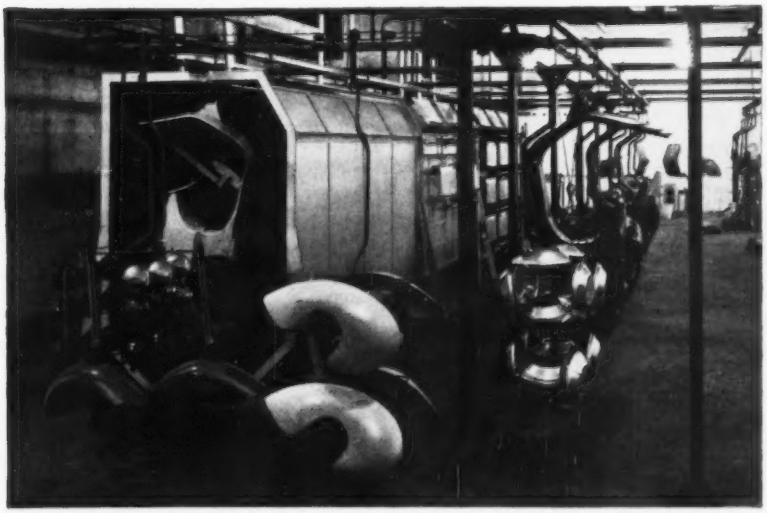


Fig. 3. Gas-fired paint stoving oven for Vespa parts including chassis, lamp housings, steering columns with mudguards, engine wings and fan cowlings, installed at Douglas Engineering (Kingswood) Ltd.

Scottish Gas Board, Edinburgh.
Northern Gas Board, Newcastle-upon-Tyne.
North Western Gas Board, Manchester.
North Eastern Gas Board, Leeds.
East Midlands Gas Board, Leicester.
West Midlands Gas Board, Birmingham.
Wales Gas Board, Cardiff.
Eastern Gas Board, Watford.
North Thames Gas Board, London, W.8.
South Eastern Gas Board, Croydon.
Southern Gas Board, Southampton.
South Western Gas Board, Bath.

The Gas Council, 1 Grosvenor Place, London, S.W.1.

NEW 'ACHESON' TRADE MARK TAPER JOINTED ELECTRODES NOW AVAILABLE

16″, 14″ and 12″ diameter "Acheson" Graphite Electrodes with taper jointing have now been introduced to join the well established 20″ taper jointed electrodes. The new 16″ diameter electrode has a nipple with a major diameter $8\frac{3}{4}$″ and length 12″. This means a thicker socket wall all round in addition to the extra protection and life given to the socket by the 1 in 6 taper. The new 14″ diameter taper electrode also gives a thicker socket wall and is machined to take a nipple 8″ at the major diameter and 10″ long. Similarly the new 12″ taper electrode is machined for a nipple 7″ maximum diameter and $8\frac{1}{2}$″ long.

For maximum security and tightness of joints the threading of nipple and socket is four threads per inch machined to fine tolerances to ensure perfect matching of tapers.

Full information about these three important additions to the "Acheson" range can be obtained from British Acheson Electrodes Limited, Wincobank, Sheffield (Tel: Rotherham 4836).

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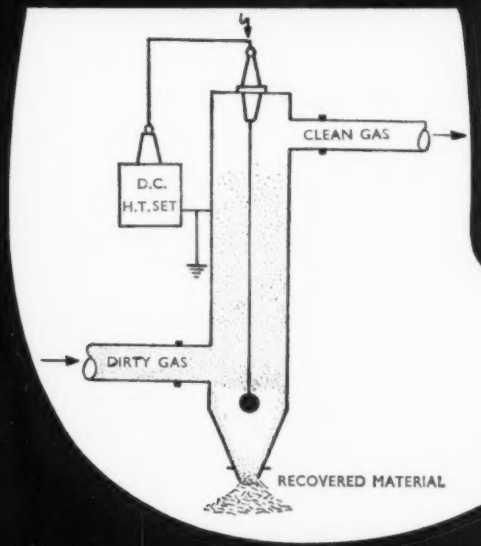
GRAPHITE ELECTRODES

The term 'ACHESON' is a registered trade mark

Give up smoking!



You can't afford smoke nowadays – it's bad for you and it's bad for other people too. For clean air you need the very best in electro-precipitation. That is what our extensive research and development resources, backed by unrivalled experience, can give you. Pollution from the chimneys of power stations, iron and steelworks, chemical plants and other industrial plants all over the world has been cut to a minimum by our high-efficiency electro-precipitation. It's time your chimneys, too, gave up smoking!

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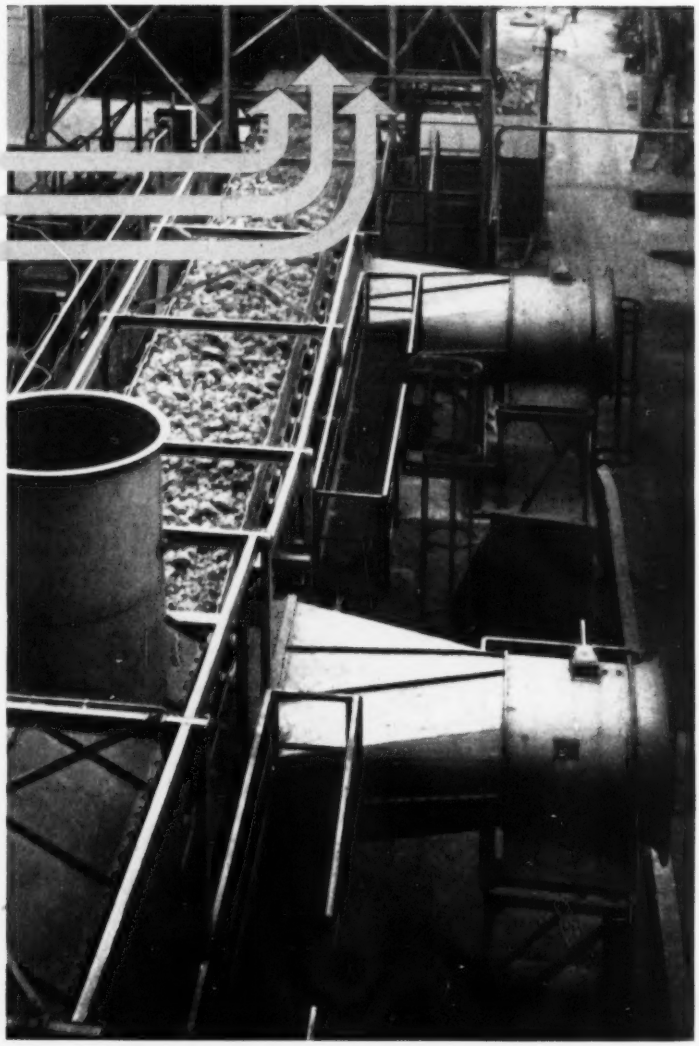
SPEEDING THE SINTER FLOW

This photograph was taken looking down on the sinter cooler at Barrow Ironworks. On the right of the cooler can be seen two of the three fans which have reduced the cooling interval so efficiently

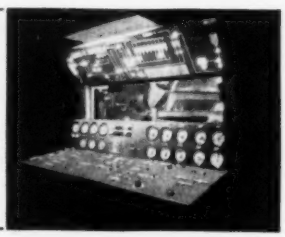


For 70 years, we have made steady improvement in the sintering process our business, and each sinter plant we design and install incorporates the latest developments in sintering technique.

At many new sinter plants, including those at Barrow Ironworks, Consett Ironworks, the Iron and Steel Corporation of South Africa, Cockerill-Ougrée (Belgium) and the Société Métallurgique de Normandie (France), a new Huntington Heberlein cooler has increased the efficiency of the sinter process. High quality sinter is being cooled in 20 minutes from 600°C for transmission on normal belt conveyors. This cooling is achieved by forced circulation from cold air fans which work at very low power consumptions.

Associated in the U.S.A. with Koppers Company Incorporated, our other specialities include: Ore Dressing Plants, High Intensity Magnetic Separators, Herreshoff Furnaces and Badische Turbulent Layer Roasters.

The feed rate control panel at Barrow



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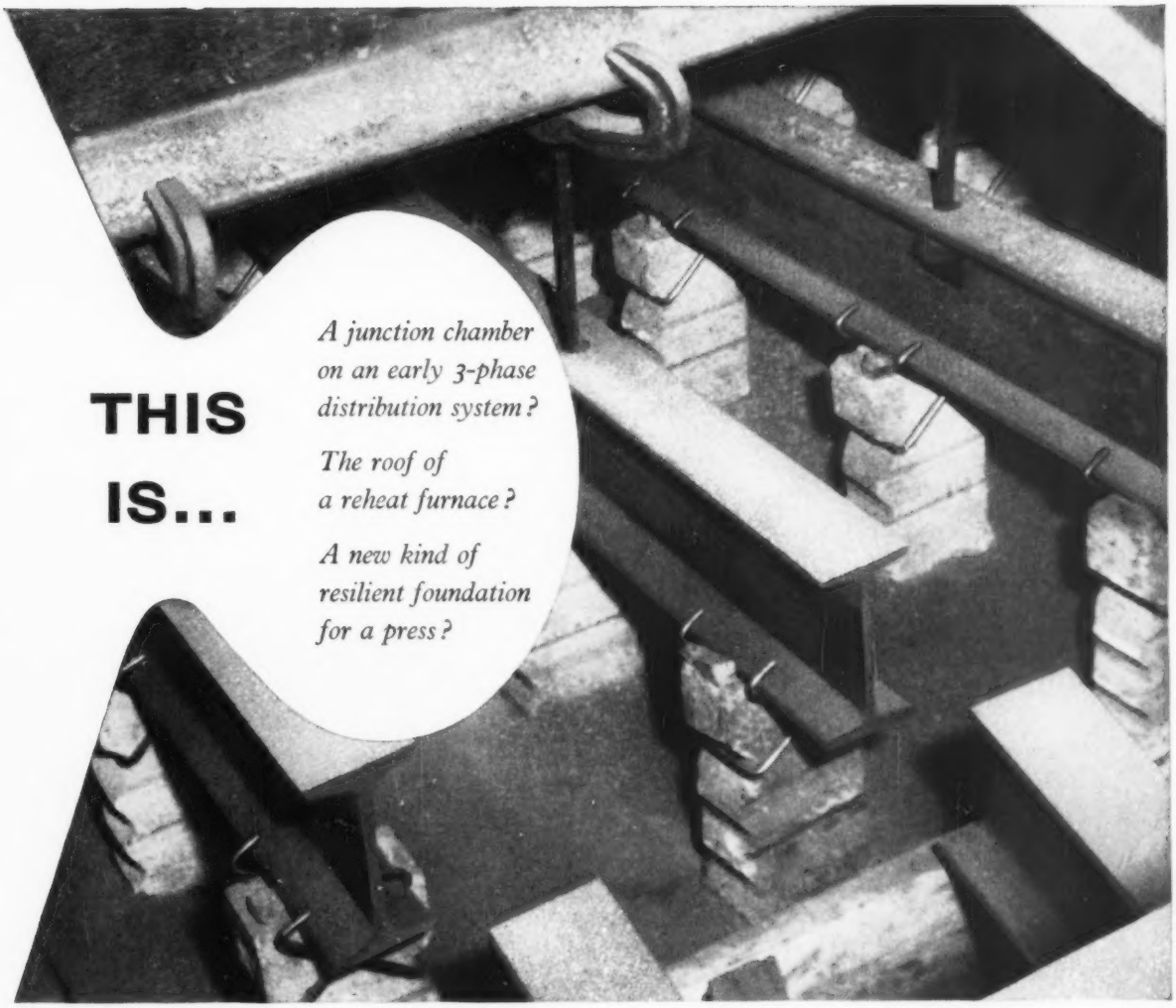
THIS IS...
A junction chamber on an early 3-phase distribution system?
The roof of a reheat furnace?
A new kind of resilient foundation for a press?

Number two is the right answer. It is part of the monolithic roof of a reheat furnace at the Margam works of the Steel Company of Wales, immediately before the refractory was placed.

The special anchor bricks hanging from the R.S.J's are secured by heat-resisting clips and will provide support through the full thickness of the refractory lining.

This roof was cast in "TRI-MOR" High Temperature Castable. It is a good example of the type of furnace lining which "TRI-MOR" refractories and Morgan's whole-hearted belief in monolithic structures have made possible.

Some of the most useful of the "TRI-MOR" refractories are:—

TRI-MOR Standard Castable
TRI-MOR High Strength Castable
TRI-MOR High Temperature Castable
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TRI-MOR Dense 'Guncrete'
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MORGAN Refractories Ltd

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More protection for hands and machines-

New Shell Dromus Oils

Most modern soluble cutting oils contain phenolic compounds used as coupling agents between the oil and the emulsifier, for better blending and easier mixing. These phenolic compounds can cause skin irritation, especially where modern high-speed machines are used and the emulsion can concentrate, through the evaporation of water, above the safety level.

Shell research chemists have been working on this problem, which has been causing some concern to Management. After considerable research, the Shell Dromus Oils have been reformulated and these new cutting oils now produce bland emulsions, which considerably reduce the risk of skin trouble to operators.

The real difficulty was to find a new coupling agent to replace the phenolic compounds, and Shell finally used what their chemists know as a higher fatty alcohol complex. This solved one problem, but presented another. The new coupling agent was volatile at the high temperatures normally used in blending processes. Further research found a solution to this problem by designing and installing new plant.

The new Dromus Oils are every bit as efficient as before and cost no more. They put Management in the welcome position of being able to minimise working hazards at no extra cost. And machine men need no longer be so worried about skin troubles.

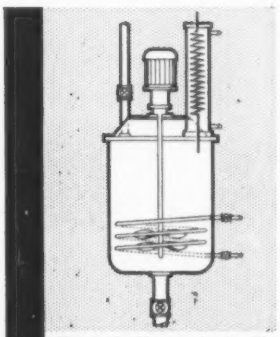
The moral of the story is that Shell research is supremely applicational. The centre at Thornton is always ready to work with even the most specialised sectors to produce the right oil for the job. If you and your organization have any major lubricating problems, it pays to get in touch with your local supplier of Shell Industrial Lubricants.

The Research Story

Shell chemists in the U.K., in Holland and in the U.S.A., prepared and examined hundreds of experimental soluble oils, and established that certain combinations of fatty alcohols could be used in place of phenolic compounds with no loss of efficiency. They set to work to discover the best combination and developed a higher fatty alcohol complex which fitted exactly. Then they realised that to blend this new coupling agent into soluble oils would require special plant and new blending techniques.

Exhaustive testing of blend stability, emulsion stability, anti-corrosion and machining properties led to selection of the most promising blends. A pilot plant was set up to produce batches of these for use in field trials.

This field testing and final development proceeded for two years whilst production plants were erected at points so chosen as to give the most economical and rapid delivery throughout the United Kingdom.



This is the blending kettle. The reflux condenser beside the stirrer motor prevents the loss of constituents volatile at the blending temperature.

NEW SHELL DROMUS SOLUBLE CUTTING OILS

another proof of Shell leadership in lubrication

The heat-shock resistance of Vitreosil ensures accurate thermo-couple temperature readings without the slightest risk of contamination in molten steel. The cost of Vitreosil Dipping Tubes, from a few pence each, is negligible in relation to the loss incurred in a sub-standard casting. Full list of sizes and prices on request.

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LONDON: 9, BERKELEY STREET, W.1. *Tel. Hyde Park 1711/2.*

Sole Distributors for Dipping Tubes in the United Kingdom
THE AMALGAMS CO. LTD., TINSLEY PARK ROAD, SHEFFIELD, 9.
LAND PYROMETERS LTD., QUEENS ROAD, SHEFFIELD, 2.

Thornton

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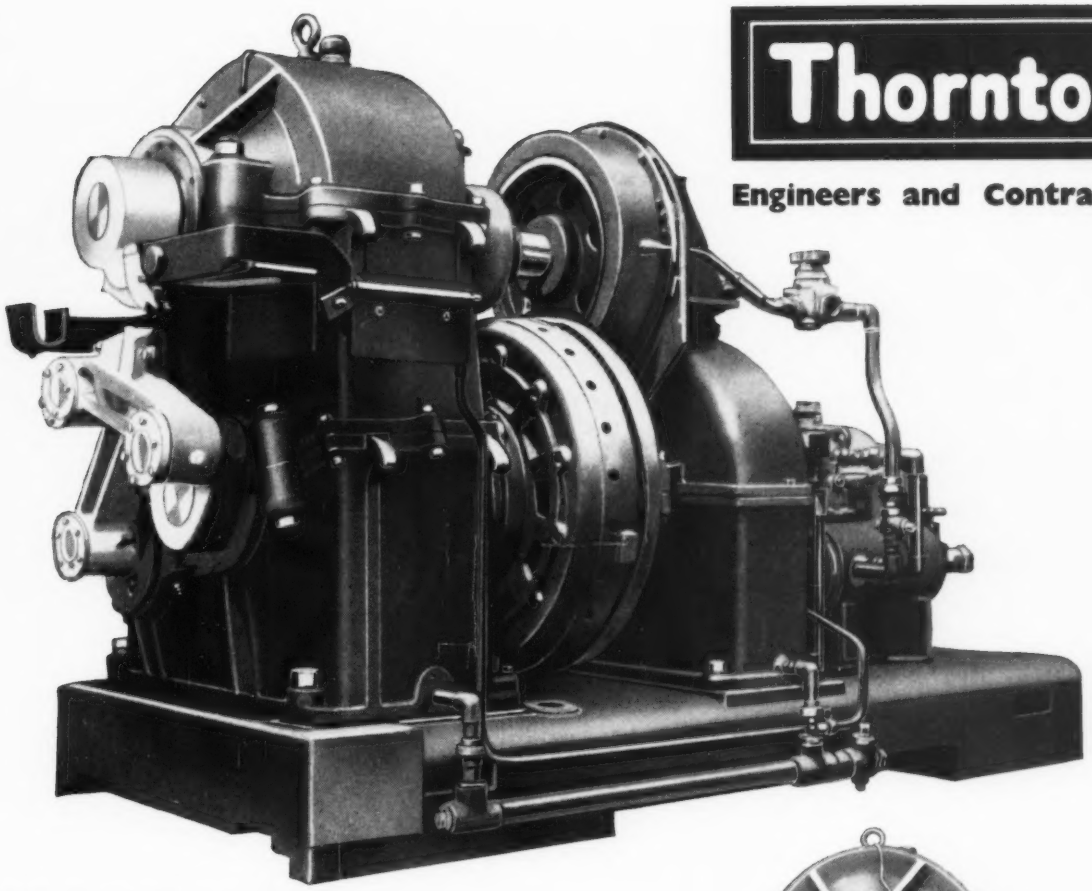

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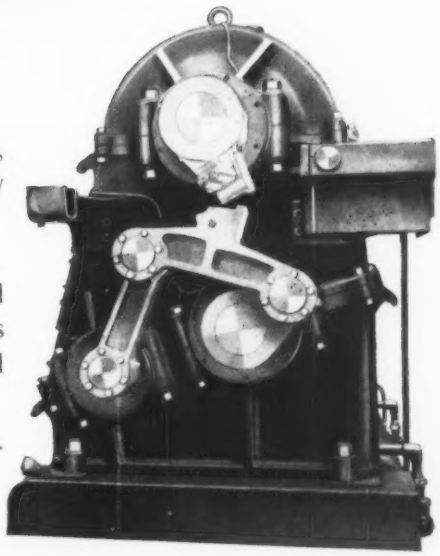
Bogies of all kinds for carrying light or heavy loads.
General Engineering work of various kinds.
We shall be glad to quote against your requirements and specifications.



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Cast steel corrugated Slag Pot, weight approximately 10 tons.

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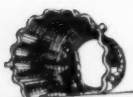

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ELECTRIC OVERHEAD TRAVELLING CRANES

★ *a view of the cab showing the seat control unit.*

The Adamson 50/10 ton crane is the third of a series of new design supplied to Richard Thomas & Baldwins Limited, Ebbw Vale Section. Features of the crane include monolithic construction of the crab and the elimination of castings by mild steel fabrication of the hoist barrel and bottom block. The cab is of particular interest as it incorporates the most modern type of seat unit ensuring maximum vision and ease of control. Joseph Adamson electric overhead travelling cranes can be supplied to all specifications including cranes suited to the most exacting 24 hours-a-day process work.

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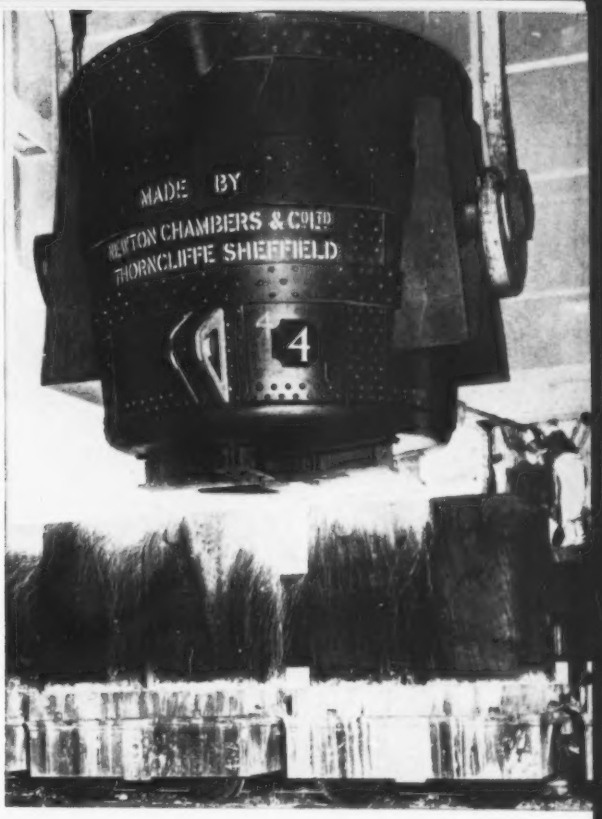
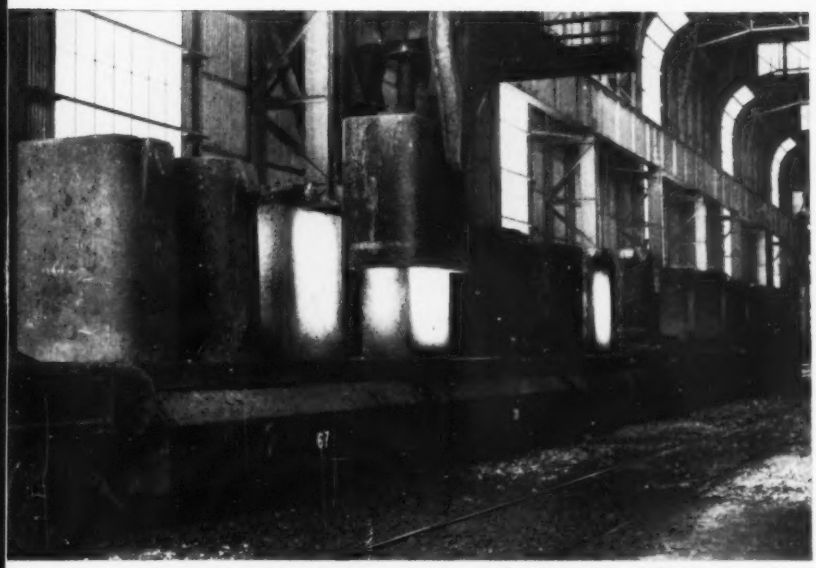
THE ADAMSON GROUP

STEEL WORKS PLANT

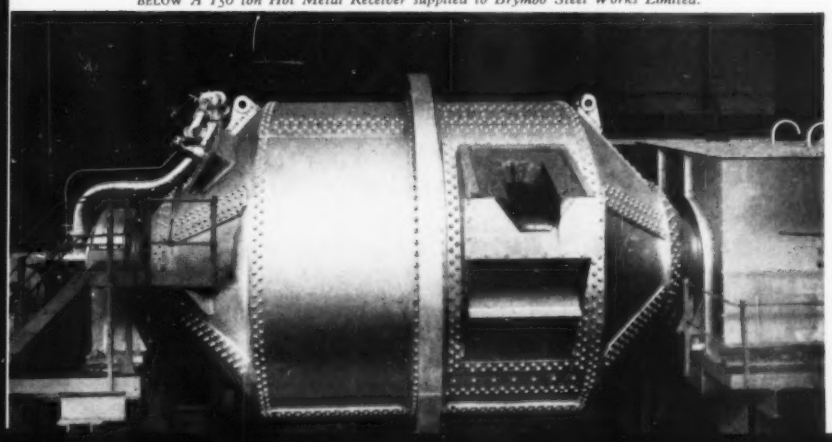
by Newton Chambers



RIGHT *275 ton capacity Steel Casting Ladles for John Summers and Sons Limited.*



ABOVE *Two Bogie type Ingot Casting Cars supplied to the Steel Co. of Wales.*
BELOW *A 150 ton Hot Metal Receiver supplied to Brymbo Steel Works Limited.*



NEWTON CHAMBERS bring to the service of the steel industry years of specialist experience in the design and manufacture of heavy steelworks plant and equipment, and are keeping abreast of modern requirements by their own developments and by entering into arrangements to manufacture new types of plant developed overseas.

Recent extensions to our shops, with the provision of new equipment, enable us to make even larger, heavier and more intricate fabrications. Today, we are one of the largest suppliers of steelworks ancillary plant, including ladles up to 300 tons capacity.

- **Slag Ladles and Carriages**
- **Hot Metal Ladles and Carriages**
- **Casting Ladles and Carriages**
- **Ingot Casting Cars**
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- **Special Transport Equipment**
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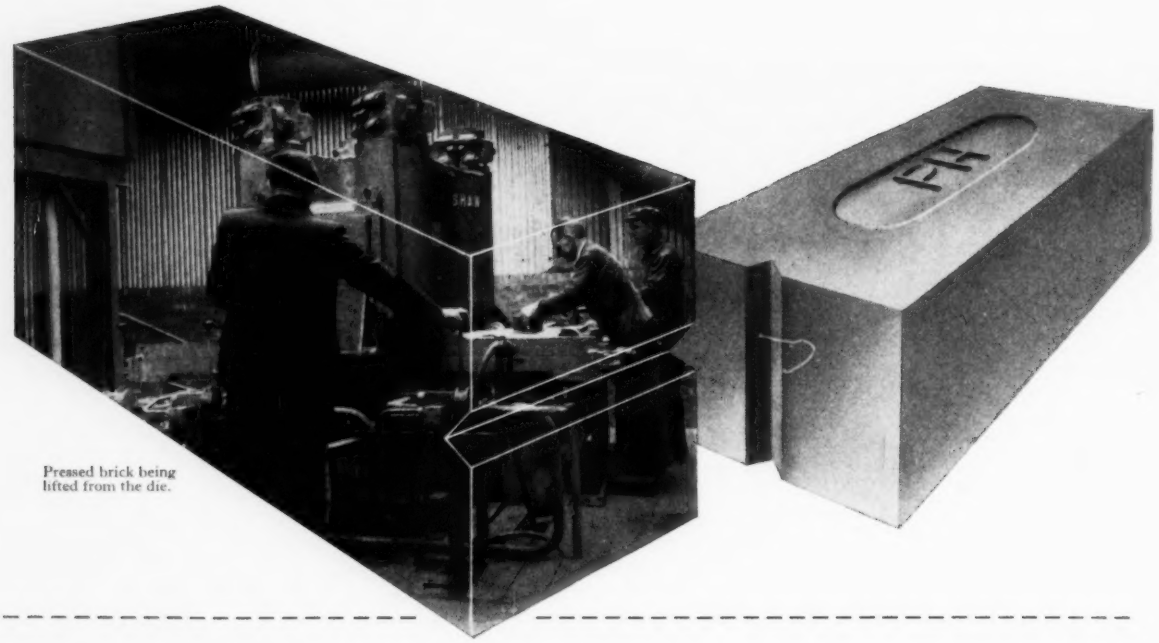
- **Recuperators and Heat Exchangers**

Newton Chambers

ENGINEERING DIVISION
THORNCLIFFE · SHEFFIELD



Pressed brick being lifted from the die.

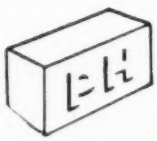
PRESSING PROBLEM SOLVED

Pickford Holland install the latest hydraulic presses for standard and special shapes

Refractory bricks today must be absolutely accurate in size and shape. These qualities, combined with unerring consistency in texture and performance are achieved by Pickford Holland through the medium of the most modern plant and equipment.

In Pickford Holland works, the very latest crushing, grinding and mixing plant, powerful hydraulic presses and continuous tunnel firing kilns have been and are being installed. Rigid control of the various processes is strictly observed, and the finished bricks are carefully inspected and tested before being despatched to the consumer.

More and more Pickford Holland refractory bricks are being supplied to steel and other industries throughout the world and the demand still grows. This surely points to the success of this policy of plant modernisation and is a tribute to the lasting service that these bricks give.



PICKFORD HOLLAND *Refractory Bricks*

Consistent in Size, Shape, Texture and Performance

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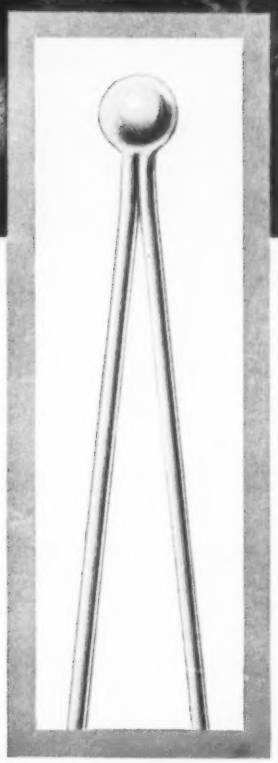
Spectacular...but



. . . but dependent so much upon the unspectacular—the platinum:rhodium-platinum thermocouple, which plays a vital role in all high-temperature processes where accurate measurement is essential to exact control.

Simple, robust, consistent, the thermocouple is to both industry and research a means without equal of precise high-temperature determination.

Information regarding the properties of the platinum metals and their industrial application is freely available.

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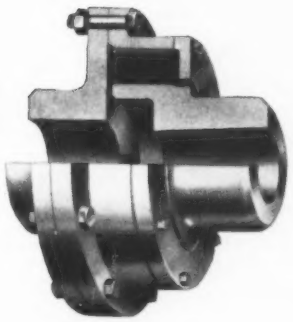

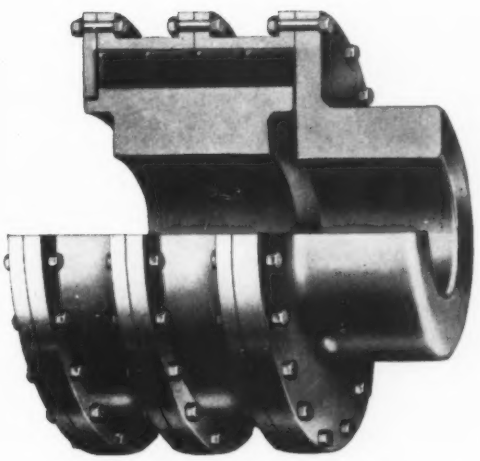

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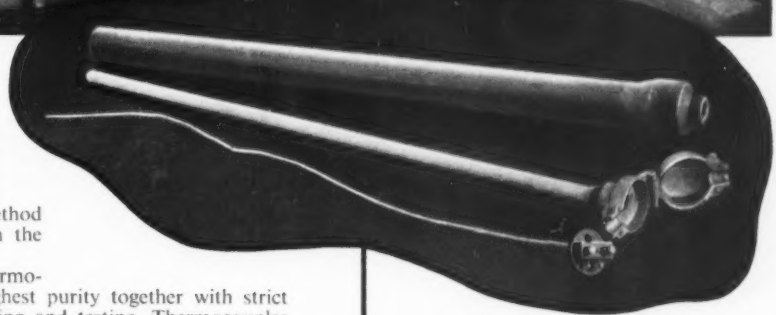

A view of the electric soaking pits at the works of The Consett Iron Company, which are controlled by means of 95% platinum—5% rhodium versus 80% platinum—20% rhodium thermocouples.

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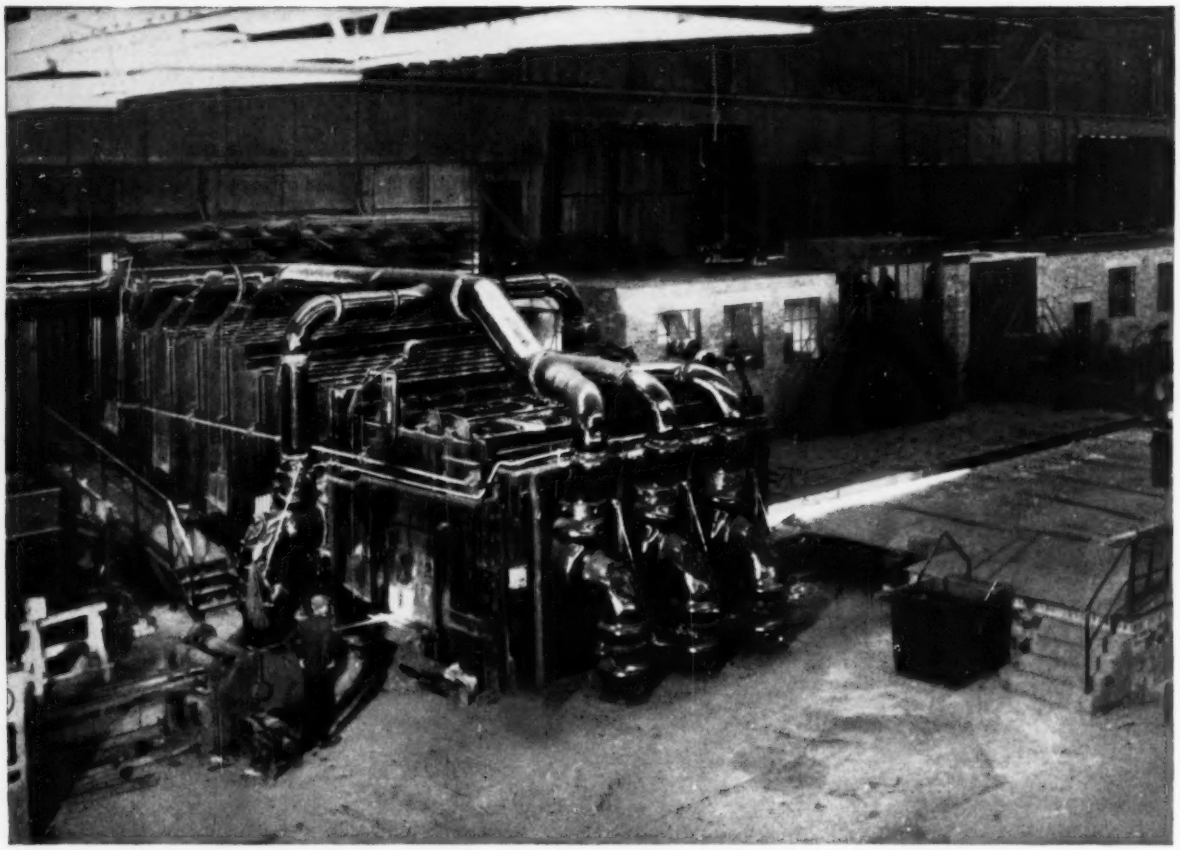

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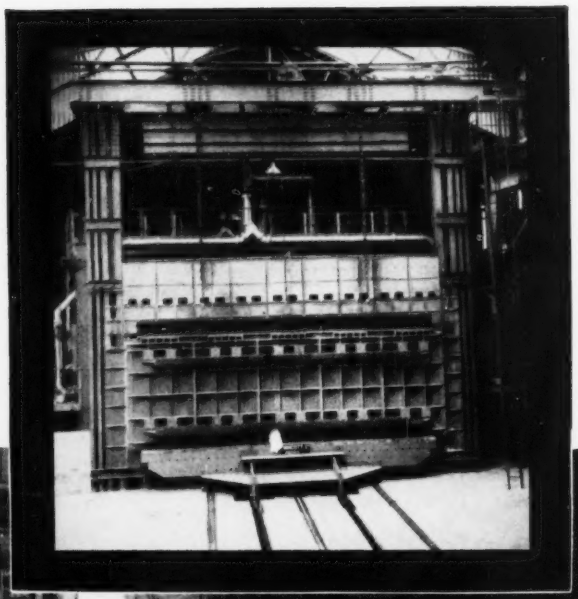

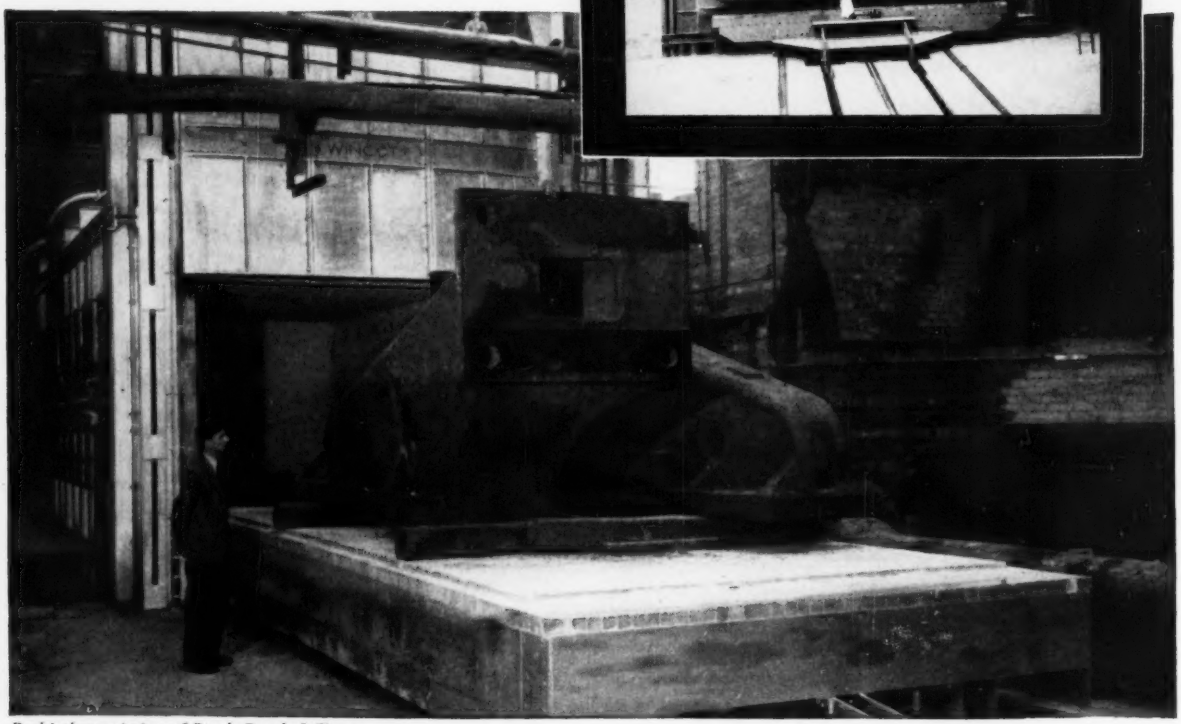

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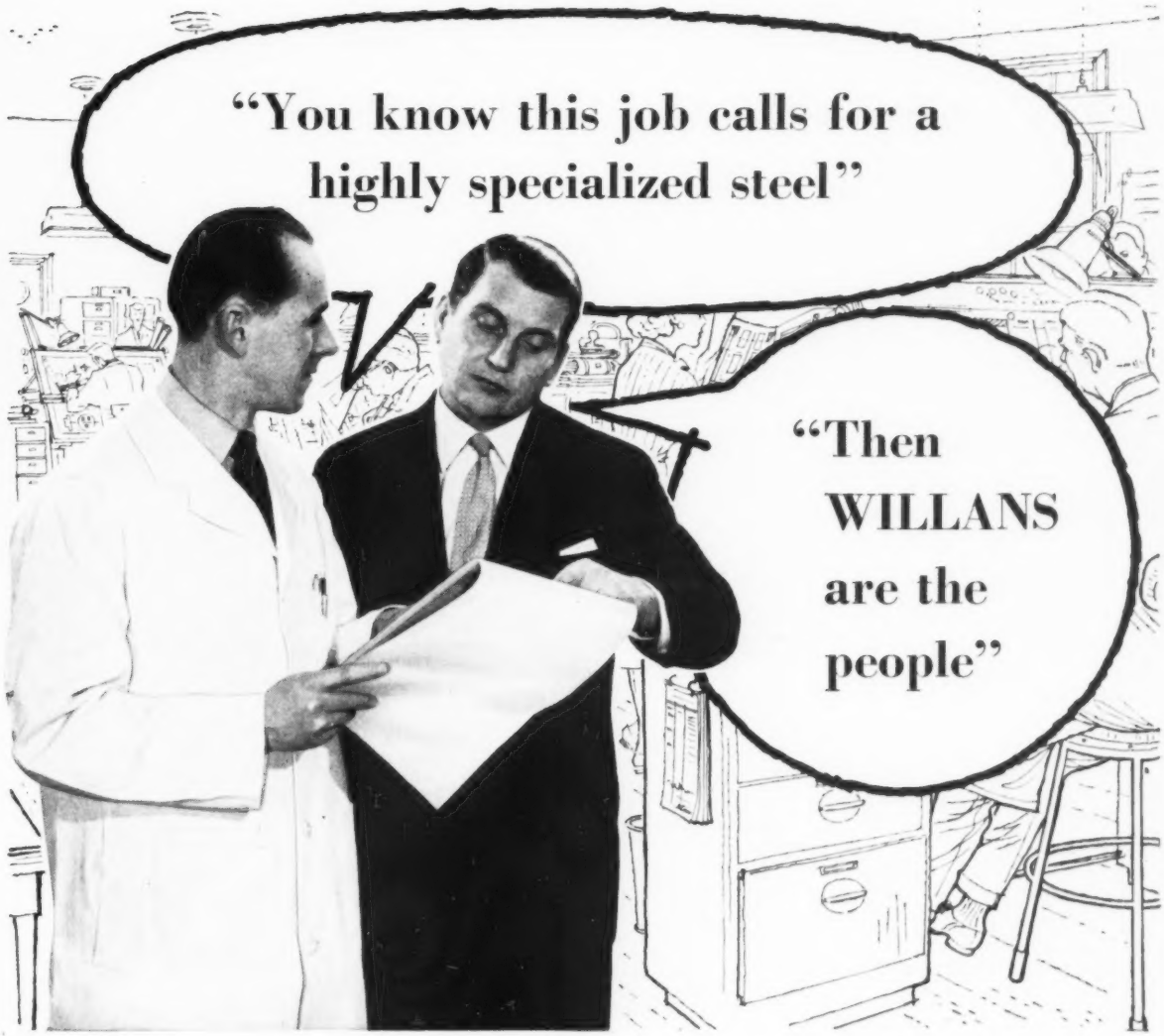

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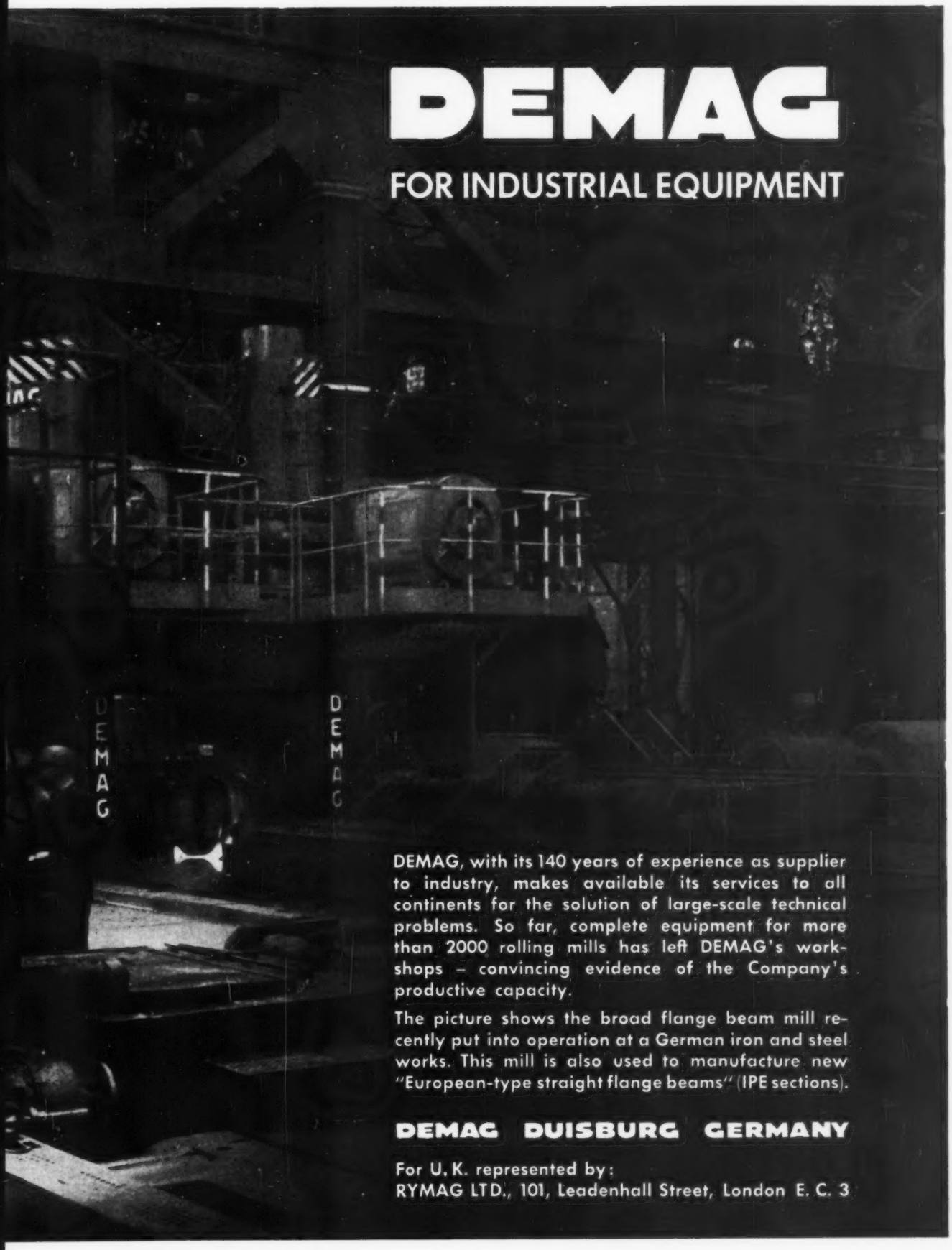

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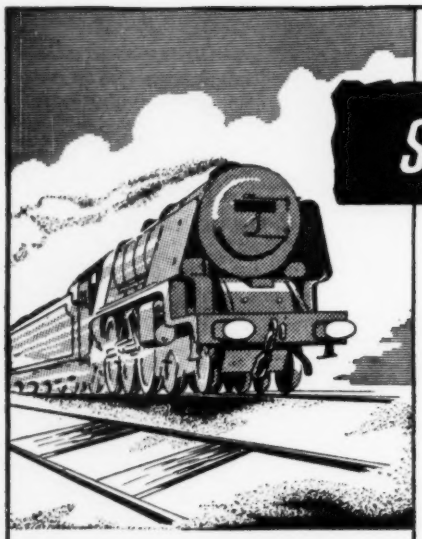

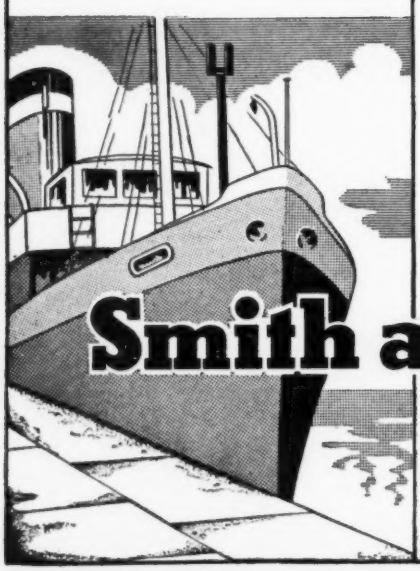

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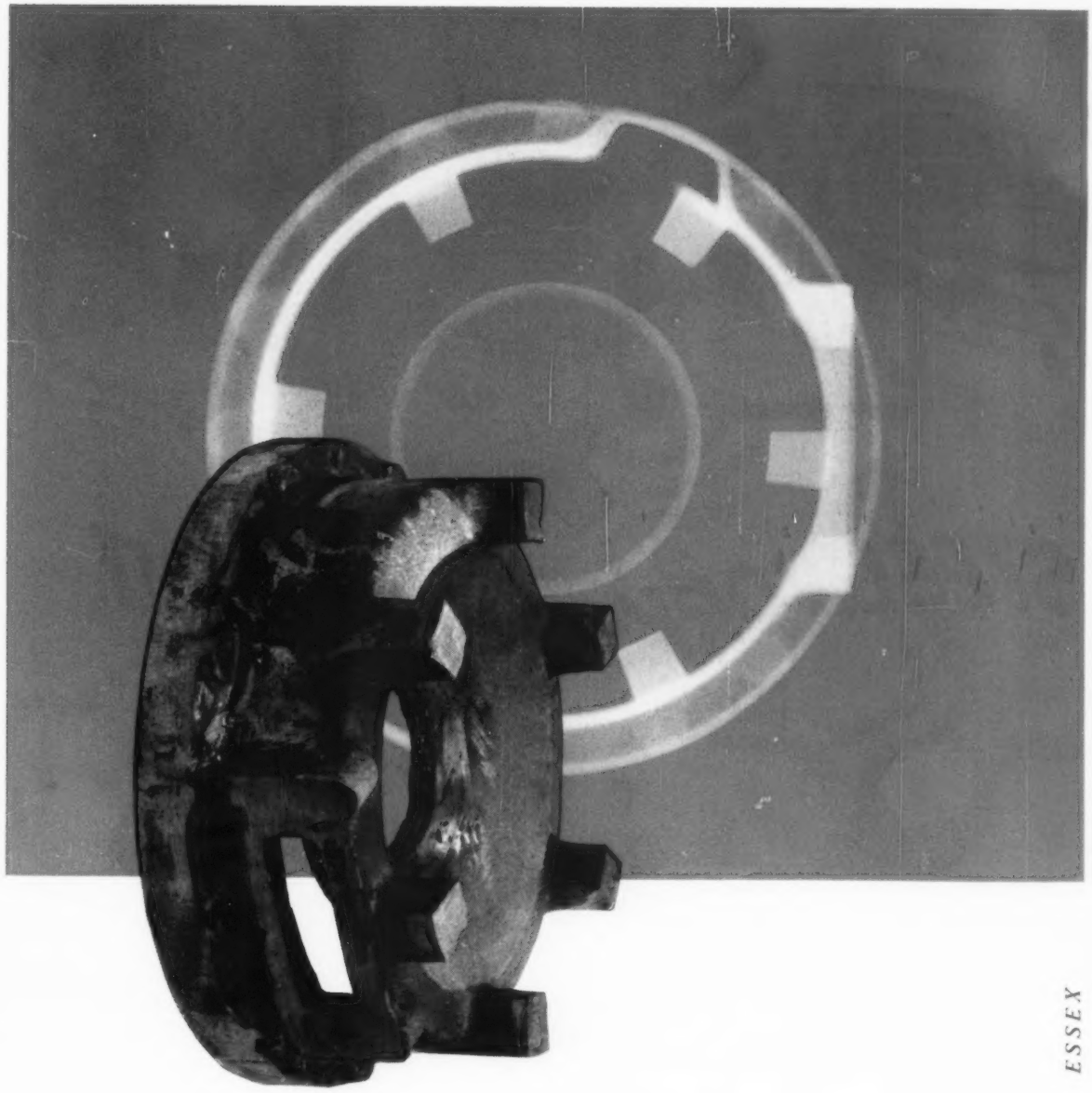

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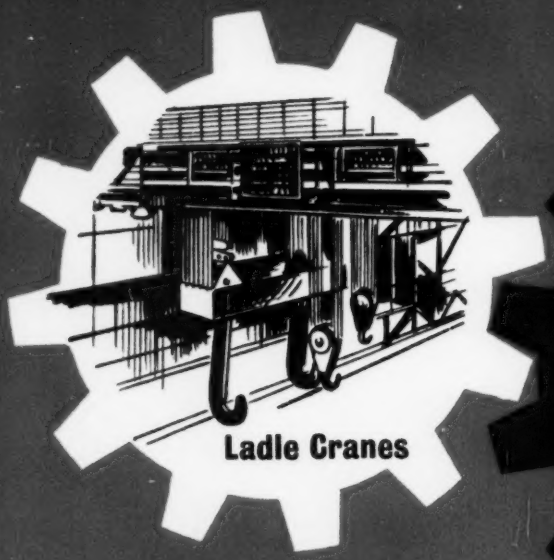

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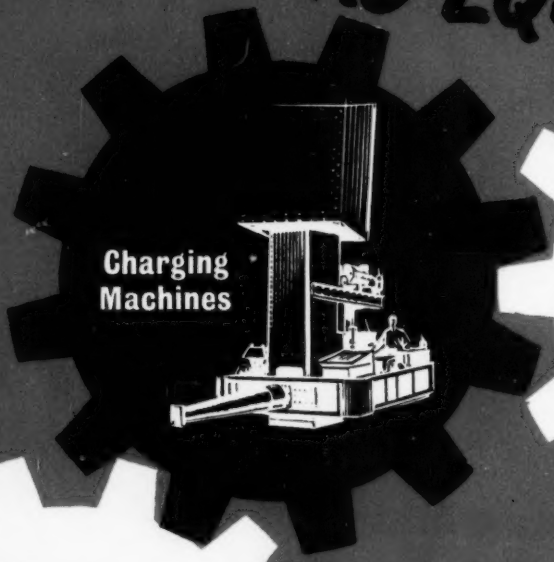

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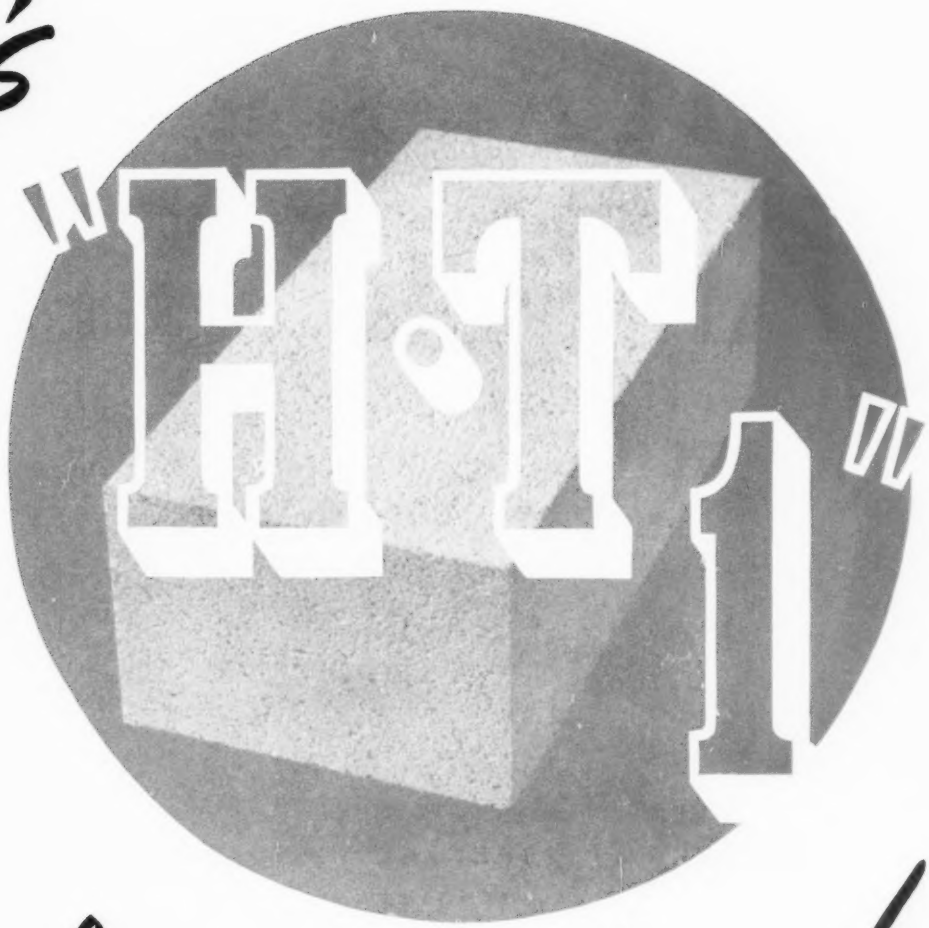

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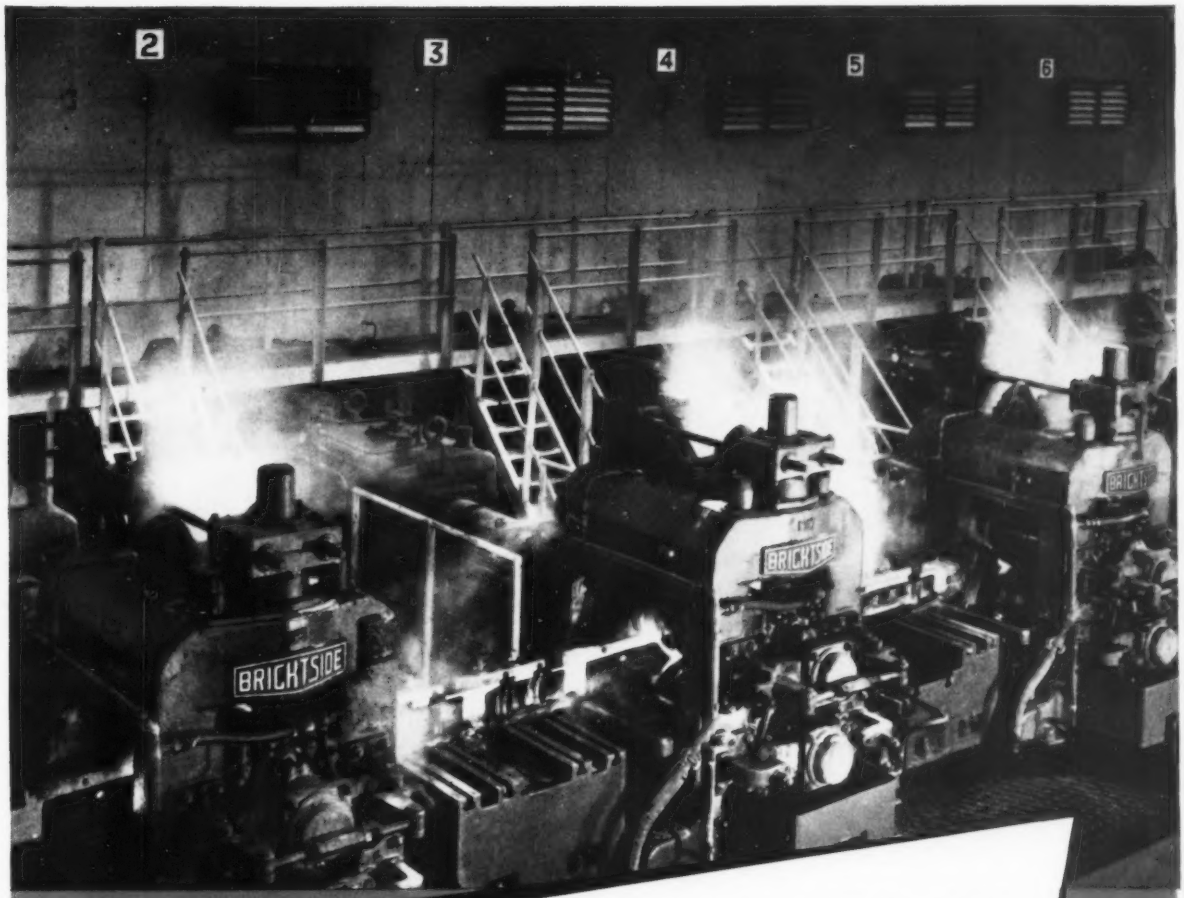

Roughing Train of Continuous Bar Mill
(Photograph by courtesy of The Park Gate Iron & Steel Company Ltd.)

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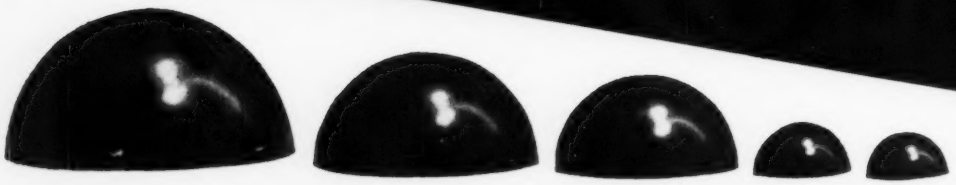

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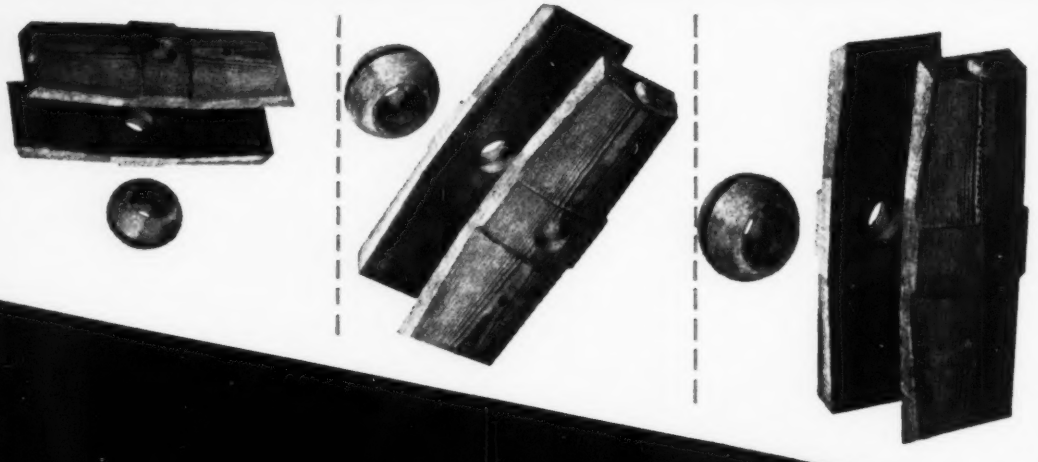

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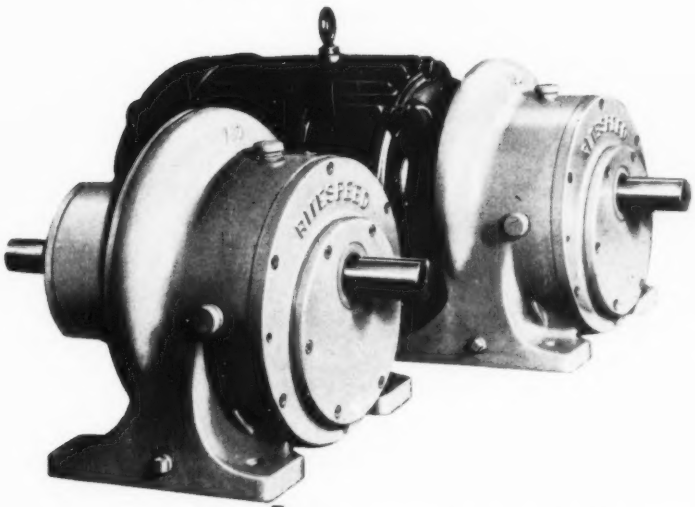

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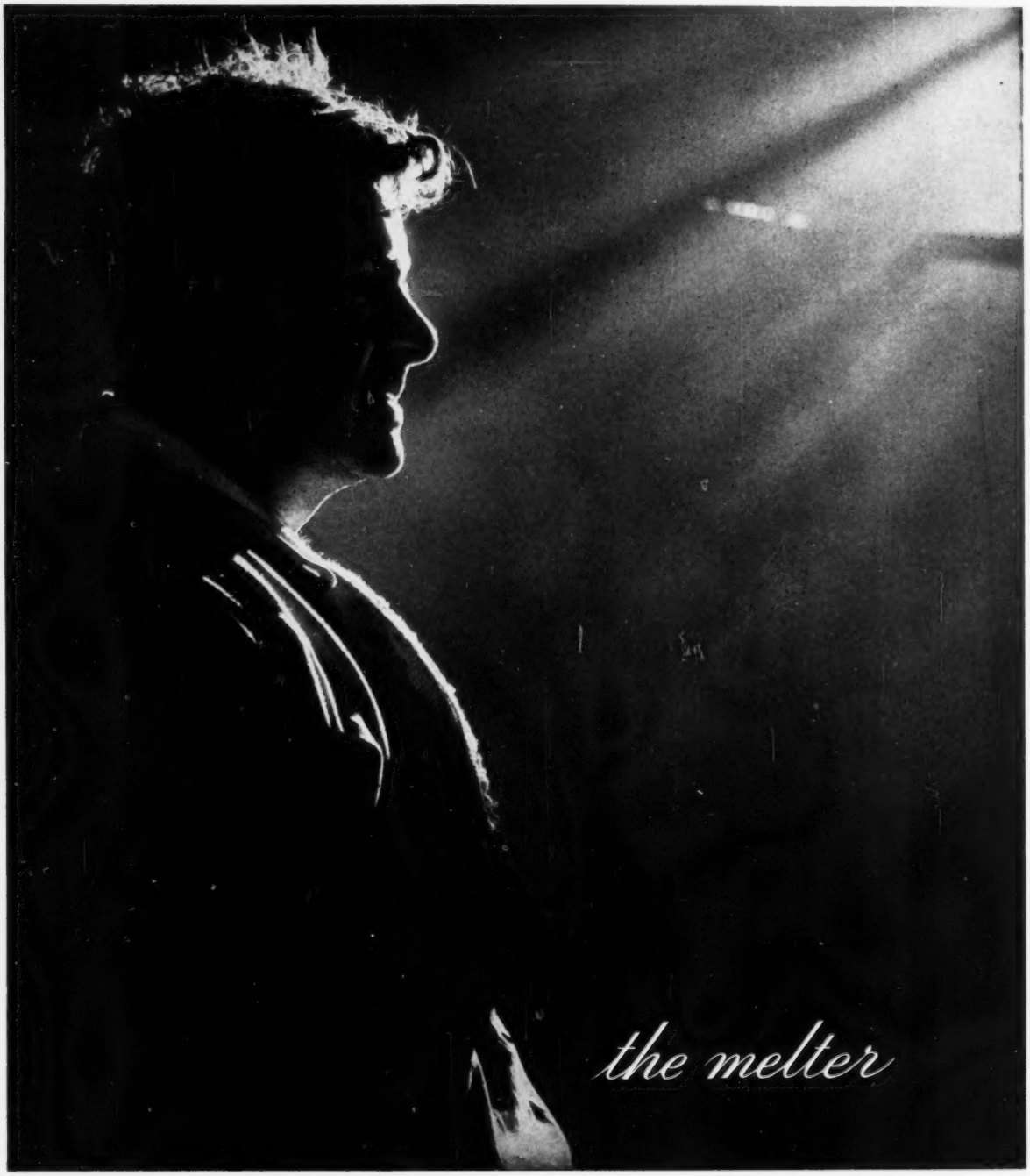

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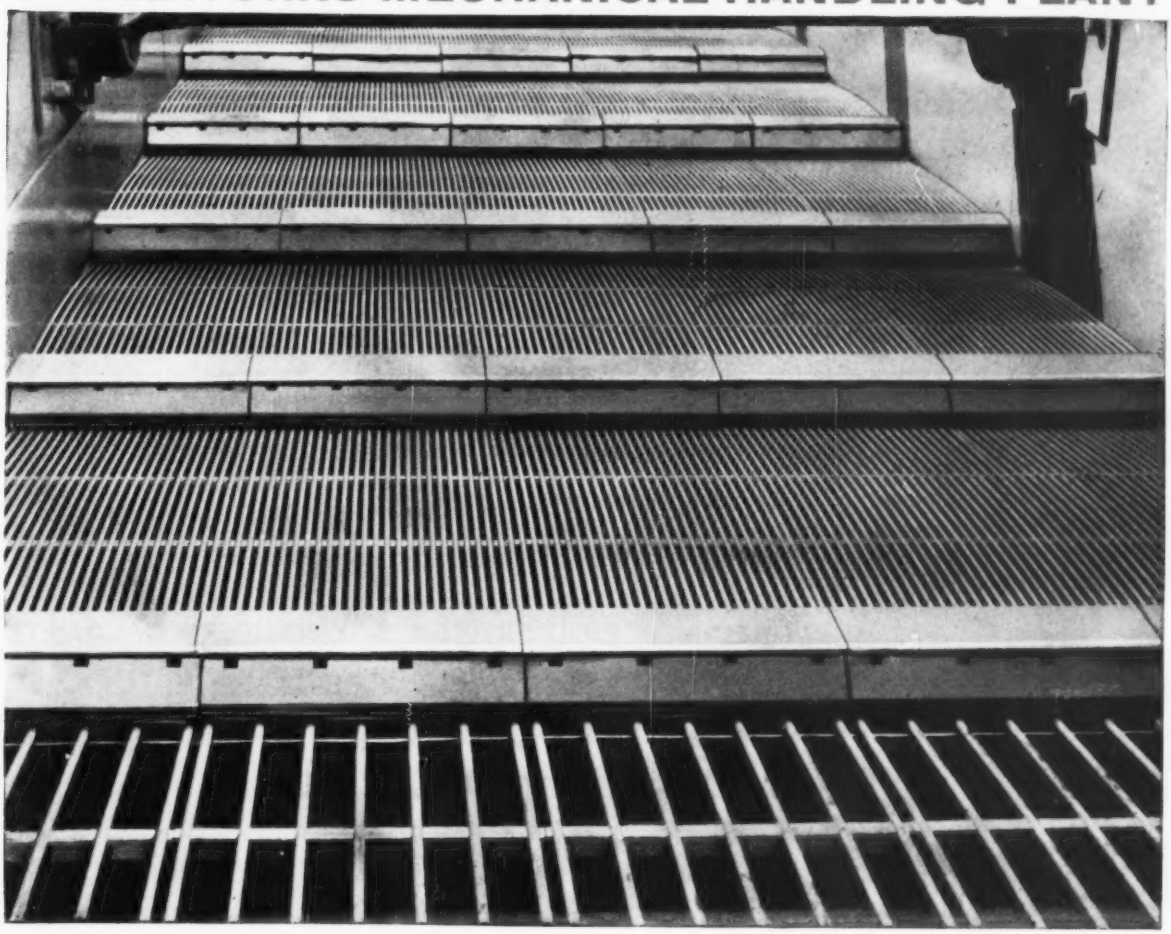

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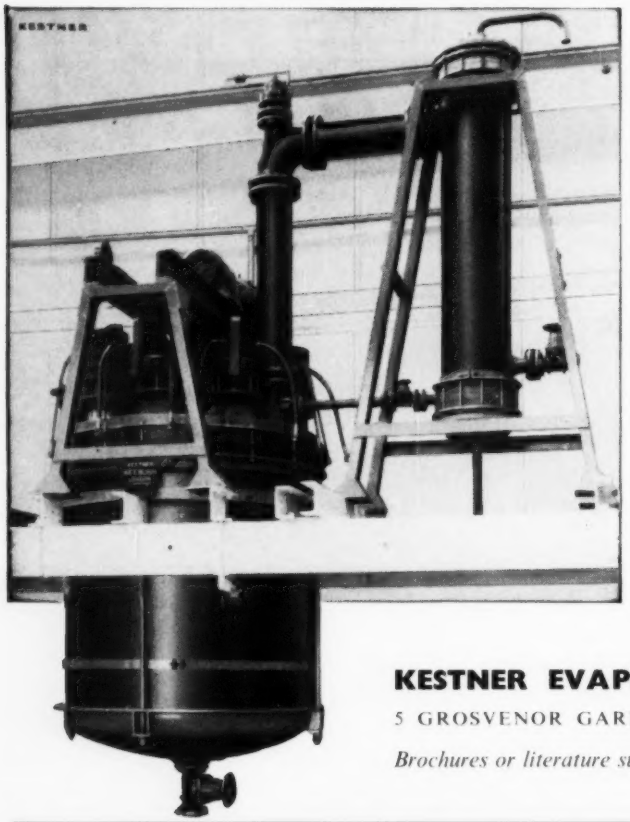

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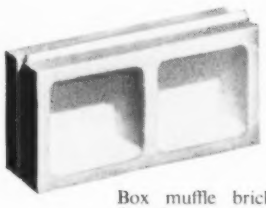

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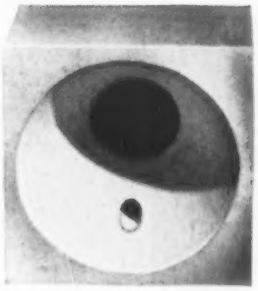

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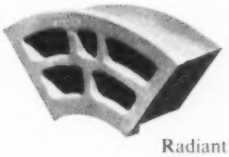

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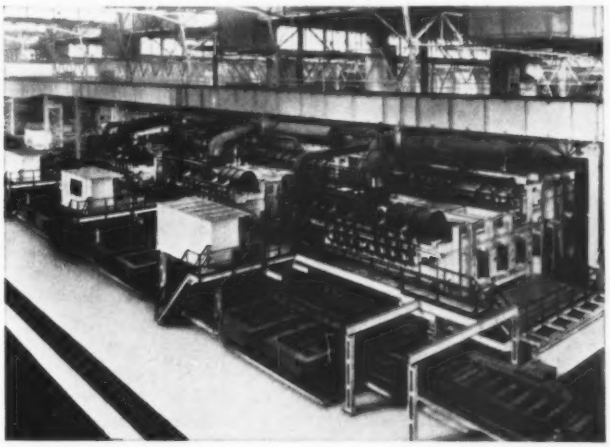

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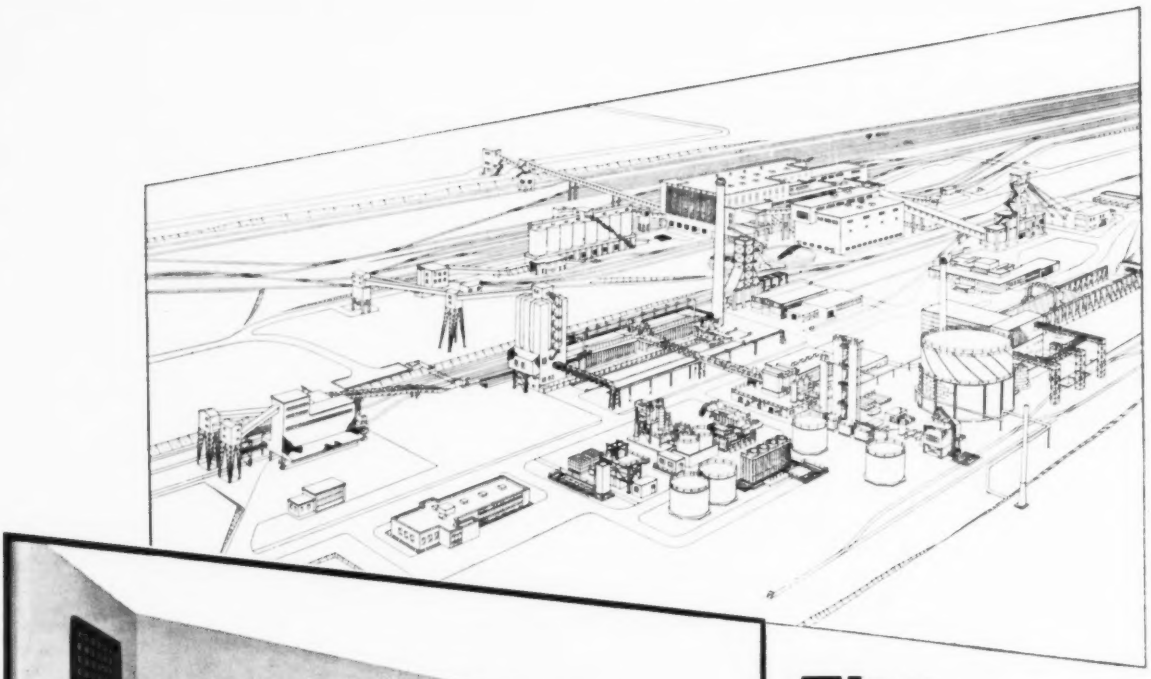

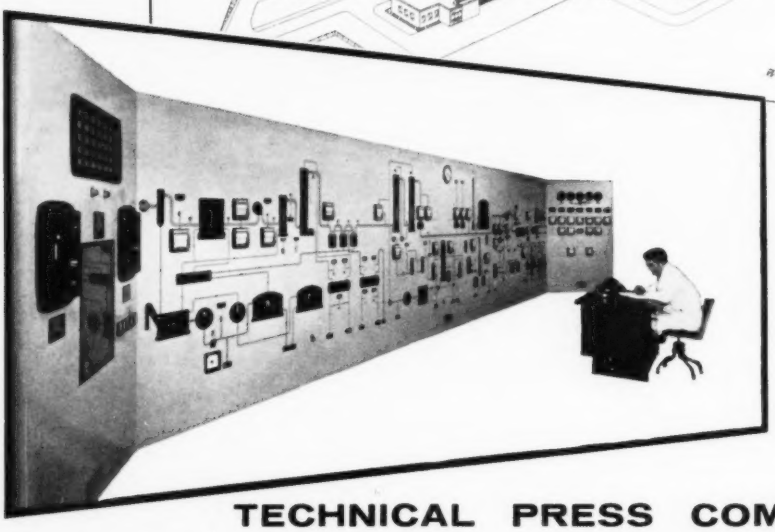

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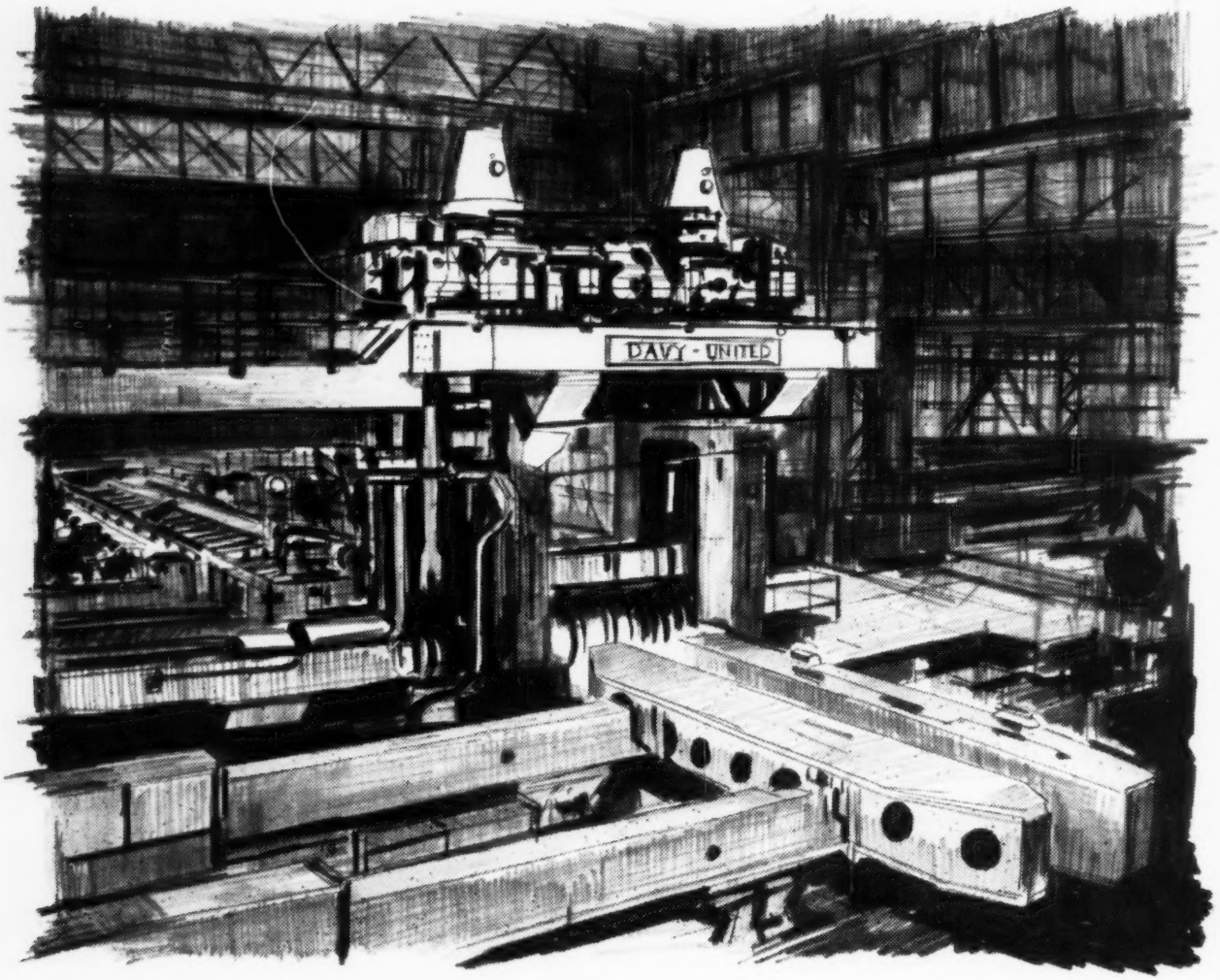

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MAJOR B. CHETWYND TALBOT, son of the late Benjamin Talbot, a Past-President and Bessemer Gold Medallist, was born at Harrogate in 1901 and educated at Eton and Cambridge. He joined the South Durham Steel and Iron Company Ltd in 1922 and spent his early years in the company's mineral department. In 1926 when steel pipe production began at Stockton, Major Talbot played a prominent part in this new venture. In 1934 he was transferred to London as manager and two years later he was appointed a director of the company. From September 1939 to January 1945 Major Talbot was abroad on active service in the Middle East, Italy, and North West Europe, and was mentioned in dispatches. In 1947 he was appointed deputy chairman and general manager of the South Durham Steel and Iron Company, and on the death of his father in the same year he became managing director. Two years later he was also appointed chairman of the company.

Major Talbot has been a member of the Executive Committee of the British Iron and Steel Federation since 1947 and was elected to the Development Committee in 1957. During the past 12 years he has served three times as chairman of the North-East Coast Steelmakers' Association and as chairman of the Rail Makers' Association.

During recent years Major Talbot has been a frequent visitor to the USA and Canada and has secured valuable contracts for natural-gas pipelines which have been installed for the development of the natural-gas resources of Canada.

Major Talbot is also a director of Cargo Fleet Iron Company Ltd, British Basic Slag Ltd, South Durham Steel Pipes (Canada) Ltd, The North Yorkshire Shipping Company Ltd, and a member of the Tees Conservancy Commission. He became a member of The Iron and Steel Institute in 1926, joined the Council in 1952, and was elected a Vice-President in 1959.

B. Chetwynd Talbot, T.D.
Vice-President

Factors affecting the transition temperatures of forgings used in power-generating equipment

B. Cina, B.Sc., Ph.D., and P. Jubb, B.Sc.

SYNOPSIS

It has been found that the principal metallurgical factors affecting transition temperature in low-alloy steels are ferrite grain size, tensile or yield strength, and susceptibility to temper embrittlement. The grain size of the ferrite is governed by that of the parent austenite and by the temperature at which the latter transforms. For a given transformation product, quantitative relationships have been derived between transition temperature and parent austenite grain size, tensile strength, and carbon content. These relationships, together with a knowledge of the susceptibility to temper embrittlement, have been successfully used to account for the transition temperature of material from large forgings and have indicated the lines along which efforts should be made to lower these transition temperatures. 1636

INTRODUCTION

MANY INVESTIGATIONS have been carried out on the problems associated with the brittle fracture of large structures such as ships. As a result, considerable attention is being paid to the transition temperature of the materials of construction such as ship plate, etc. Whilst the normal criteria used to determine the transition temperature have been chosen in a somewhat arbitrary manner, it is generally agreed that the result obtained does give qualitative information relating to the resistance to brittle fracture. More recently, investigations by Winne and Wundt[1] suggest there is probably a correlation between the impact transition temperature as determined from small test pieces cut from large forgings and the bursting strength of large discs cut from the forgings and containing sharp notches artificially introduced at the centre of the forgings.

The present work was concerned with the large forgings used in turbo-alternators. These forgings were of two types; rotor shafts up to 36 ft long, and turbine wheels up to 62 in. outside dia. The first step in an attempt to reduce the transition temperature of such large forgings appeared to be to examine the effect of different metallurgical variables on an arbitrarily defined transition temperature. This investigation forms Part I of the present paper. It is somewhat academic in scope in that the effect of the variables has been examined irrespective of possible practical application of the results.

In Part II, a study was made of the effect that these variables were having in practice on the impact transition temperatures of samples from actual production forgings. These transition temperatures cover a range of more than 100° C, but most of the variation can be explained in terms of the results given in Part I.

Manuscript received 24 November 1958.
The authors are with the Brown-Firth Research Laboratories, Sheffield.

PART 1: FACTORS AFFECTING THE TRANSITION TEMPERATURE OF BAR MATERIALS

Previous work

It was already known from experience, or the literature,[2-23] or suspected, that transition temperature was affected by five principal factors:

(i) austenite transformation product
(ii) tensile strength
(iii) grain size
(iv) temper embrittlement
(v) composition.

Whilst other workers have investigated these five factors affecting transition temperature, in no case were all these factors controlled simultaneously. In particular, it was common for the tensile level to be varied by tempering at temperatures liable to introduce temper embrittlement, which detracted from the value of the results, not only as it affected the transition temperature but also by fundamentally changing the nature of the brittle failure from cleavage of the ferrite grains to a tendency to intergranular failure at the prior austenite grain boundaries. In addition, different criteria of transition temperature were used to assess the effect of the several variables. Such

TABLE I Analyses of alloys, wt-%

Cast no.	Quality	C	Si	Mn	S	P	Cr	Ni	Mo	N
22 730	En 19	0·41	0·27	0·65	0·040	0·027	1·26	0·16	0·33	0·005
22 869	En 20	0·42	0·25	0·66	0·039	0·027	1·42	0·19	0·72	0·005
65 937	En 21	0·32	0·27	0·61	0·019	0·014	0·08	3·05	...	0·011
89 449	En 25	0·25	0·21	0·64	0·008	0·012	0·71	2·73	0·60	0·012
90 706	En 40A	0·18	0·29	0·51	0·015	0·010	3·35	0·26	0·47	0·014
86 519	En 40B	0·26	0·25	0·52	0·006	0·012	3·25	0·18	0·55	0·012
88 501	En 40B	0·30	0·24	0·48	0·003	0·014	3·11	0·21	0·52	0·014
91 373	En 40B	0·25	0·30	0·51	0·009	0·013	3·06	0·17	0·56	0·013
94 544	En 40B	0·26	0·24	0·50	0·003	0·013	3·12	0·26	0·53	0·015
83 099	5%Cr–Mo	0·19	0·34	0·38	0·005	0·014	5·36	0·19	0·53	0·015

criteria make comparisons difficult, and are themselves of variable merit.

Austenite transformation product

From the several studies[2-8] of the effect of microstructure on the transition temperature of any given steel, it can be concluded that for the same tensile strength, the lower the austenite transformation temperature, the lower the transition temperature. However, in almost every case, [2, 4-8] the tempering temperatures employed were likely to have introduced some degree of temper embrittlement, while in Rinebolt's work[3] the tensile level was not kept constant. Precise quantitative results cannot therefore be obtained from the foregoing work. There is one exception in one of Davenport's experiments[7] in which a Ni–Cr–Mo steel was athermally transformed to pearlite, bainite, or martensite. Samples representing each microstructure were then tempered at 650° C to the same tensile strength. A progressive decrease in transition temperature was found with decreasing transformation temperature. For a tensile strength of about 58 tons/in², the Charpy transition temperature was 141° C lower for bainite than for pearlite, and 57° C lower for martensite than for bainite; the criterion used for transition temperature was the temperature for 15 ft-lb energy absorption.

Tensile strength

Because of the complication of temper embrittlement, there are few data available on the effect of tensile level on transition temperature, although it is generally agreed that the transition temperature increases with tensile strength. However, for an En 16 (1½%Mn–Mo) steel containing less than 0·001%P and shown not to be susceptible to temper embrittlement, Allen and Earley[6] found that on tempering material with a martensitic microstructure, the transition temperature decreased from + 2° to − 55° C for a decrease in tensile strength from 83 to 54 tons/in². This is equivalent to a change of almost 2° C per 1 ton/in². Their results for a similar steel containing 0·055%P would definitely have been affected by temper embrittlement. Davenport[7] also gave data on the effect of tensile level on transition temperature for a Ni–Cr–Mo eutectoid steel in the quenched and tempered condition. He found that the transition temperature decreased as the tensile strength decreased from about 250 000 lb/in² to 150 000 lb/in², but further decrease in tensile level to about 100 000 lb/in² surprisingly caused an increase in transition temperature. As the tempering temperatures used are not given, it is not known whether or not temper embrittlement affected any of the results. For the higher range of tensile level, the change in 15 ft-lb transition temperature was about 9° C per 1 ton/in² change in tensile strength.

Grain size

There are two grain sizes which may affect transition temperature, that of the ferrite and that of the parent austenite. The latter is doubly important, (*a*) indirectly because it will influence the grain size of its ferrite progeny, and (*b*) directly since, if the material is temper embrittled, fracture then tends to occur at the prior austenite grain boundaries. Although some published results[9-11] suggest that in this case the larger the austenite grain size, the greater is the susceptibility to temper embrittlement, further work is required.

Ferrite grain size

It is now well established that the finer the ferrite grain size the lower is the transition temperature.[12-18] This, however, has been determined only for ferrite formed in the upper bend of the S-curve. No work has been published on the ferrite grains formed on tempering martensitic or bainitic transformation products. Quantitatively, for upper-bend ferrite, a change of grain size by one ASTM number has resulted in a corresponding change in transition temperature by 8°,[18] 10°,[14] 13°,[18] 16°,[13, 14, 16] and 20° C, the latter figure having been derived by the present authors from work by Jackson and Michie.[19]

TABLE II Heat-treatment of 3%Cr–Mo, cast 86519, for various transformation products

Transformation product	Heat treatment*
Isothermal pearlite	½ h 900° C, rapidly FC to 700° C, held 1½ h 700° C (to transform) and AC
Isothermal bainite	½ h 900° C, AC to 600° C, rapidly FC to 380° C, held 1 h 380° C (to transform) and AC + 48 h 650° C AC + 48 h 650° C AC
Martensite	½ h 900° C OQ + 4 h 720° AC

*FC = furnace cooled AC = air cooled OQ = oil quenched

TABLE III Mechanical properties of 3%Cr–Mo, cast 86519, for various transformation products

Transformation product	Limit of proportionality, tons/in²	Proof stress, % 0·05–0·1	Proof stress, % 0·2–0·5	Max. stress	True fracture stress	Elong., %	Red. in area, %	Transition temp., °C Mean energy	Transition temp., °C 50% cleavage	Transition temp., °C Average
Pearlite	19·0	22·0	22·0	44·8	81	30·5	62	43	50	47
Bainite	28·0	34·6	35·0	44·6	99·7	32	75·5	− 82	− 79	− 81
Martensite	31·0	34·4	34·4	44·2	112	35·2	78·5	− 114	− 109	− 112

Prior austenite grain size

A correlation has been shown between prior austenite grain size and transition temperature.[18, 20, 21] An increase of prior austenite grain size by one ASTM number caused an increase in transition temperature by 10–13° C for a plain carbon steel[18] and 10° C for a 1%Cr–Mo steel.[21] In the latter case, the material had been transformed to martensite and tempered at 673° C. Barr and Honeyman[22] found a correlation between transition temperature and McQuaid–Ehn grain size for mild steel, which possibly indicates that for their materials, the finer the McQuaid–Ehn grain size, the finer was the actual parent austenite grain size at the normal austenitizing temperature employed and the finer was the subsequent ferrite grain size formed.

Temper embrittlement

An excellent review on temper brittleness has been published by Woodfine[23] and it is therefore unnecessary to consider this subject here.

Composition

Composition can be expected to play at least an indirect part in affecting transition temperature in that for a given rate of cooling from the austenitizing temperature, it will determine the transformation product.

Present work

The present work was planned as a systematic study of the above factors affecting transition temperature, limiting the variables as far as possible in each case.

Materials used

The work was carried out on bar material because of its uniformity. The bars were $\frac{5}{8}$–$1\frac{1}{4}$ in. dia. and were received as hot rolled.

The compositions of all the steels studied are listed in Table I.

Details of heat-treatment and mechanical testing

The steels were all heat-treated in $\frac{3}{4}$-in. or $\frac{5}{8}$-in. dia. bar form in lengths up to about 5 in. and were subsequently machined to the required mechanical test pieces.

Most of the work was carried out on 3%Cr–Mo (En 40B) steel, but several other low-alloy steels were also studied, as listed in Table I. For much of the work, the tensile strength was kept near 45 tons/in² except, of course, where tensile strength was the principal variable. Except where otherwise stated, all the steels were austenitized at the same temperature of 900° C to keep heat-treatment conditions and the parent austenite grain size fairly constant. Most tempering treatments were carried out at 650° C, or above, to keep well away from temperatures which might give rise to temper embrittlement, the tempering time being the main variable to give the required tensile strength. En 21 steel was tempered at 625° C because 650° C was above Ac_1. Initially, the test material was air cooled from the tempering temperature to avoid quenching stresses, but in later work it was water quenched. Finally, the steels were transformed as completely as possible either to pearlite (or ferrite plus pearlite), bainite or martensite, or deliberately to mixed microstructures of pearlite plus bainite or bainite plus martensite, and then tempered as necessary.

The transition temperature was determined by means of twelve Charpy V-notch impact test pieces tested over the full ductile–brittle range of the material, duplicate tests being carried out at each temperature. The criterion used for defining transition temperature was the average of two experimentally determined parameters: (*a*) the temperature of mean energy absorption, and (*b*) the temperature at which the fracture showed 50% cleavage.

Effect of nature of transformation product on transition temperature

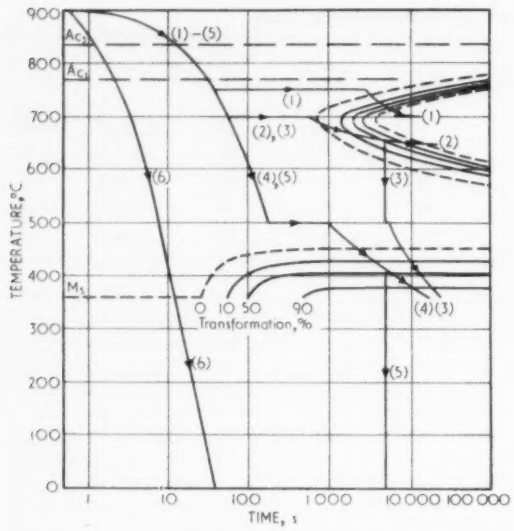
The greater part of the work in this section was carried out on 3%Cr–Mo (En 40B) steel and will be described first.

3%Cr–Mo

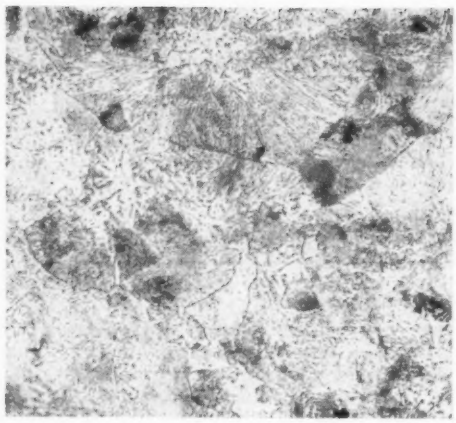
Material from cast 86519 was heat treated, as shown in Table II, to give microstructures of isothermal pearlite (plus a little free ferrite), tempered isothermal bainite, and tempered martensite. The mechanical properties so obtained are listed in Table III.

As all three microstructures have been brought to almost the same maximum stress of nearly 45 tons/in², and the parent austenite grain size, ASTM7, was common to each microstructure, the differences in average transition temperature value can probably be attributed to the different microstructures. The lower the transformation temperature, the lower is the transition temperature, a much greater difference being observed between pearlite and bainite (128° C) than between bainite and martensite (31° C), as was also found by Davenport.[7]

Having found such a marked difference between isothermal pearlite and tempered isothermal bainite or martensite, this work was repeated on 3%Cr–Mo material from cast 94544, but in this case both the pearlite and bainite were formed under athermal conditions which are more representative of practical



1 *Heat-treatment cycles for athermal transformation in 3%Cr–Mo steel, cast 94544, to (1) upper pearlite, (2) lower pearlite, (3) lower pearlite + bainite, (4) bainite, (5) bainite + martensite, and (6) martensite*



2 *Photomicrograph of 3%Cr–Mo steel, cast 94544, showing upper pearlite* × 500

conditions in the heat-treatment of forgings. In addition, the effect of microstructures consisting of roughly equal parts of athermal pearlite and athermal bainite, and athermal bainite and martensite, was investigated. The heat-treatment cycles employed are illustrated in Fig. 1. This shows cycles 1–6 superimposed on an isothermal transformation diagram[24] of a material of almost identical composition to cast 94544. Cycles 1–2 are for upper and lower pearlite respectively, cycle 4 is for bainite, cycle 6 is for martensite, cycle 3 is for a mixed structure of lower pearlite and bainite, and cycle 5 is for a mixed structure of bainite and martensite. After transformation was complete, material from the several cycles was tempered as detailed in Table IV which also lists the mechanical properties subsequently obtained.

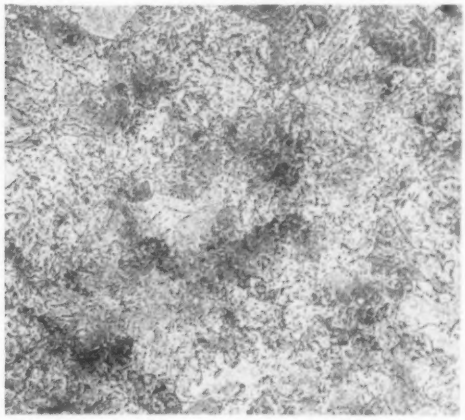
Again, all the different transformation products have been brought to nearly the same tensile strength of 45 tons/in². The parent austenite grain size common to all the samples was ASTM7–8. The final column in Table IV shows that the transition temperature decreases with decreasing transformation temperature. Microstructures consisting partly of pearlite and bainite, or bainite and martensite, have transition temperatures intermediate between those of their several constituents. Of the two pearlites, that formed over the lower range of temperature has the lower transition temperature despite its higher tensile strength. Had the tensile strengths been similar, presumably the difference in transition temperature would have been even greater. A similar effect was noted for an eutectoid Ni–Cr–Mo steel by Davenport[7] who thought it might be the net result of finer carbide dispersion and smaller ferrite grain size in the finer pearlite. The differences in transition temperature between athermal pearlite and athermal bainite, and between athermal bainite and martensite are of the same order as were obtained for isothermal pearlite, isothermal bainite, and martensite in Table III. The tendency for the average transition temperature values in Table III and IV to decrease with decreasing austenite transformation temperature may be due to a corresponding progressive decrease in ferrite grain size. This is discussed later.

TABLE IV Tempering treatments and mechanical properties of 3%Cr–Mo, cast 94544, for various transformation products

Transformation product	Tempering treatment*	Limit of proportionality	Proof stress, %				Max. stress	True fracture stress	Elong., %	Red. in area, %	Transition temperature, °C		
			0·05	0·1	0·2	0·5					Mean energy	50% cleavage	Average
		tons in²											
Upper pearlite	½ h 700°C AC	8·0	20·0	20·0	20·0	20·0	44·8	75·5	28·5	54·5	60	56	58
Lower pearlite	½ h 650°C AC	20·0	26·4	26·9	27·5	28·0	49·2	89·4	28·5	65·5	40	42	41
Lower pearlite + bainite	48 h 650°C AC + 48 h 650°C AC	21·6	28·0	28·6	29·5	30·8	45·8	95·0	32	71	−9	−7	−8
Bainite	48 h 650°C AC + 48 h 650°C AC	30·0	34·1	34·3	34·7	35·0	45·2	95·0	30	73	−65	−64	−65
Bainite + martensite	48 h 650°C AC + 48 h 650°C AC	29·0	34·8	35·2	35·9	36·9	45·8	99·0	32	74	−87	−81	−84
Martensite	4 h 720°C AC	33·0	38·8	38·8	38·8	38·8	48·4	105·7	32	75	−105	−107	−106

*AC = air cooled

3 *As Fig.2, showing lower pearlite* × 500



5 *As Fig.2, showing lower pearlite + bainite, tempered for 96 h at 650° C* × 500

Microstructures of 3%Cr–Mo

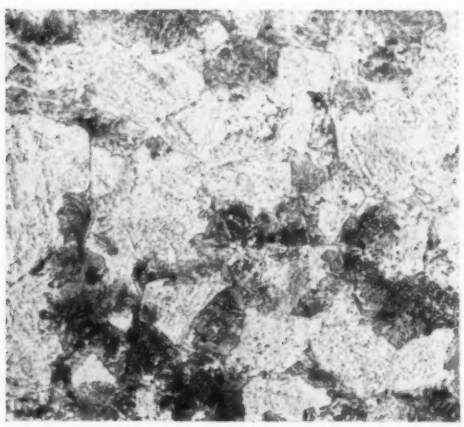
Figures 2–10 illustrate, at a magnification of × 500, the microstructures obtained after various stages of the heat-treatment cycles shown in Fig. 1 and listed in Table IV for cast 94544.

Figures 2 and 3 show the upper and lower pearlites, the latter having the finer interlamellar spacing as expected. Figures 6 and 7 represent the athermal bainite before and after tempering. The coarse bainitic laths clearly visible before tempering can only just be distinguished after tempering. This also applies to the prior austenite grain boundaries. Figure 10 shows the tempered martensitic microstructure. Figures 4 and 5 show the mixed lower pearlite and bainite microstructure before and after tempering. Because of the large amount of carbon precipitated in the pearlite, the bainite seems poor in carbon, especially in comparison with Fig. 6. After tempering, it is difficult to distinguish former pearlitic from bainitic zones. Finally, Figs. 8 and 9 show the mixed bainite and martensite microstructure before and after tempering. The bainite is here very similar to that shown in Fig. 6, as expected, but after tempering, the former bainitic and martensitic zones cannot be distinguished. X-ray diffraction examination showed that the bainitic sample contained about 15% retained austenite before tempering but this was completely transformed as a result of tempering at 650° C.

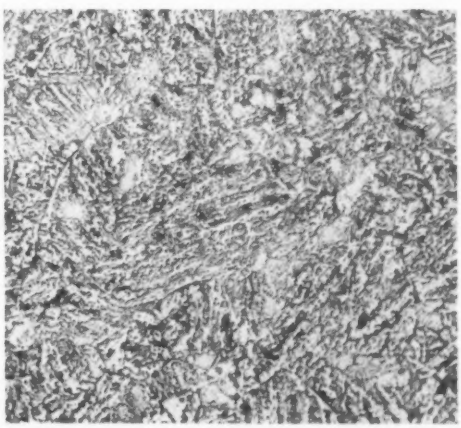
Effect of rate of cooling through the bainite in 3%Cr–Mo

The hardening treatments given to 3%Cr–Mo rotor shafts and turbine wheels result almost invariably in microstructures of athermal bainite. At the centre of a rotor shaft, the cooling rate through the bainite is about 5° C/h, while the bainite in turbine wheels is formed either on air cooling or on oil quenching, and or the latter an average cooling rate might be 250° C/h. These rates apply only to the probable transformation temperature range 450–380° C and will also vary somewhat with the size of the forging. Accordingly, the effect of such a large variation in cooling rate on the properties of the bainite was investigated on material from cast 94544.

The average cooling rate for bainite formation in cycles 3–5 in Fig. 1 was 23° C/h between 450° and 380° C. Further material was then heat-treated to give a much faster rate of bainite formation, as follows:



4 *As Fig.2, showing lower pearlite + bainite, untempered* × 500



6 *As Fig.2, showing bainite, untempered* × 500

7 *As Fig.2, showing bainite, tempered for 96 h at 650°C* × 500

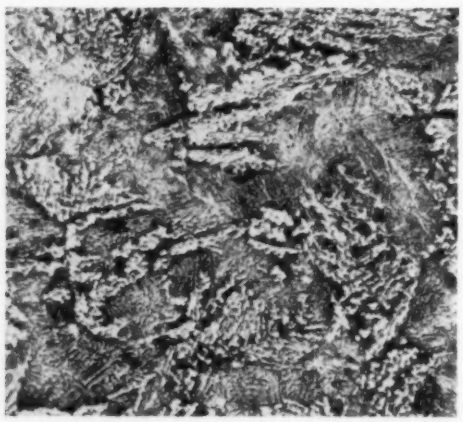
½ h/900° C, AC to 500° C, 15 min/500° C (to equalize), FC to 290° C in 28 min (to transform), and AC + 48 h/650° C AC + 48 h/650° C AC.

The average cooling rate between 450° and 380° C was 825° C/h. Figures 11 and 12 show the microstructure of this material before and after tempering. The bainitic laths in Fig. 11 are finer than those formed at 23° C/h and illustrated in Fig. 6. X-ray diffraction examination showed about 10–15% austenite retained in the bainite as formed at 825° C/h. The mechanical properties of the tempered 'fast' bainite are given in Table V.

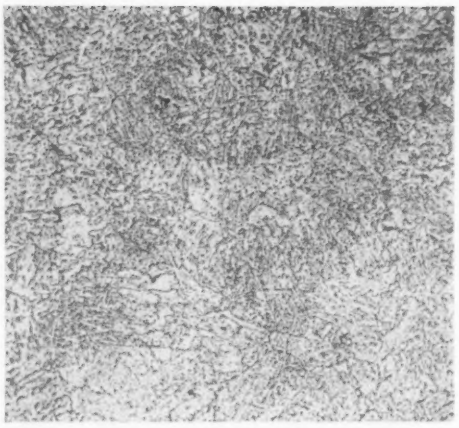
For almost the same tensile strength, the bainites formed on cooling at 825° C/h and 23° C/h have exactly the same average transition temperature. The explanation for this may be that the bainite has been formed over almost the same temperature range 450–380° C in both cases, as can be seen from the published TTT diagram[24] of material of almost identical composition.

Athermal v. *isothermal bainite formation*

If the explanation given at the end of the last paragraph is correct, bainite formed isothermally at 380° C should have a different transition temperature from that formed athermally between 450° and 380° C. The former should be lower because of the lower trans-



8 *As Fig.2, showing bainite + martensite, untempered* × 500



9 *As Fig.2, showing bainite + martensite, tempered for 96 h at 650°C* × 500

formation temperature in line with the results in Tables III and IV. This was found to be the case.

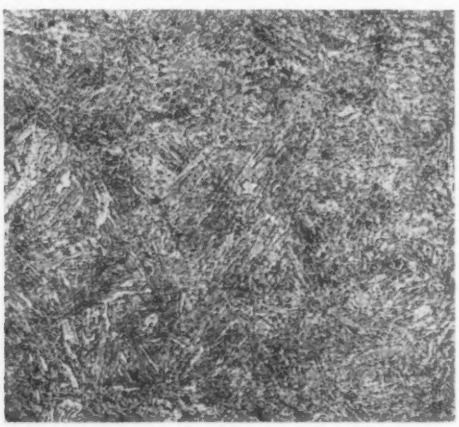
Material from cast 91373 was heat-treated as detailed in Table VI and gave the mechanical properties listed in Table VII.

For almost the same tensile strength, and the same parent austenite grain size of ASTM 8–10, the average transition temperature of the isothermal bainite is 14° C lower than that of the athermal bainite, in keeping with previous arguments.

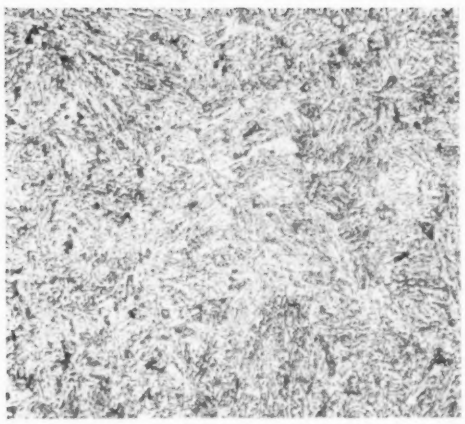
Effect of transformation product in other low-alloy steels: 1%Cr–Mo (*En 19 and En 20*), 3%Ni (*En 21*), 2½%Ni–Cr–Mo (*En 25*), *and* 5%Cr–Mo

The effect of transformation product on the transition temperature of steels in the above title was studied because the compositions of these steels are somewhat similar to those of materials used in power-generating equipment, and also to show that the effect observed was not peculiar to 3%Cr–Mo.

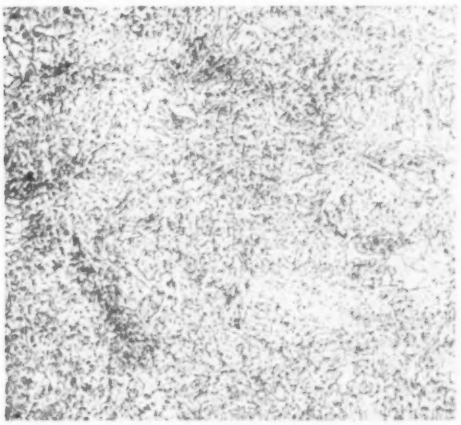
These various materials were heat-treated to give isothermal pearlitic, athermal bainitic, and martensitic microstructures and were tempered where necessary to give maximum stress values of about 45 tons/in². Some typical results are given in Table VIII, which



10 *As Fig.2, showing martensite, tempered for 4 h at 720°C* × 500



11 *As Fig.2, showing bainite formed at 825°C/h, untempered* × 500



12 *As Fig.2, showing bainite formed at 825°C/h, tempered for 96 h at 650°C* × 500

also includes the results for En 40B, taken from Table III, for comparison.

For each steel in Table VIII, the lower the transformation temperature of the austenite, the lower is the transition temperature. This comparison is made at a roughly constant level of tensile strength, except in the case of En 19 where the tensile strength of the pearlite was 9·5 tons/in² greater than that of the tempered martensite. However, in the latter case, even after allowance for the difference in tensile level (*see later*), the transition temperature of the martensite was still very much lower than that of the pearlite.

Effect of tensile strength on transition temperature

The work in this section was confined to 3%Cr–Mo (En 40B) steel. Material from cast 94544 was heat-treated as in cycles 6 and 4 in Fig. 1 to give martensitic and athermal bainitic microstructures, and tempered to give tensile strengths varying from about 36 to 75 tons/in². Details of the tempering treatments and the resulting mechanical properties are given in Table IX.

The average transition temperature values in Table IX are plotted as a function of tensile strength in Figs. 13*a* and *b*. For tensile strengths greater than about 50 tons/in² there is a progressive increase in transition temperature with tensile strength, the relationship being linear for tempered martensitic microstructures and probably so for bainitic microstructures, although the scatter is here somewhat greater. The slopes of these lines are 3° C/ton/in² and 5° C/ton/in² for tempered martensite and bainite respectively. At lower tensile levels, there is an inversion in the transition-temperature/tensile-strength relationship such that further decrease in tensile strength is accompanied by an increase in transition temperature. The inversion occurs at about 49 and 44 tons/in² tensile strength for bainite and martensite, respectively. A similar effect was observed by Davenport[7] and there was possibly a suggestion of it in Allen and Earley's work.[6]

Figure 13 also includes the transition temperatures of the two pearlitic samples whose mechanical properties were listed in Table IV. Taken together with curves *a* and *b*, they illustrate the dependence of transition temperature on microstructure.

Effect of grain size on transition temperature

Parent austenite grain size

Since, in the absence of temper embrittlement, fracture takes place by cleavage, i.e. it is transcrystalline, the relevant grain size should be that of the ferrite. However, as the latter grain size was believed to be determined to some extent by that of its parent austenite, and as it had been shown[18, 20, 21] that there was a relationship between parent austenite grain size and transition temperature, this relationship was investigated in the present work.

Again, the work was confined to 3%Cr–Mo (En 40B) steel and only bainitic microstructures were studied. Most work was done at a tensile strength level of about 48 tons/in², but two transition temperatures were determined at a tensile strength of about 67 tons/in².

Material from cast 94544 was austenitized for ½ h at temperatures of 900°, 1 000°, 1 100°, 1 175°, and 1 250° C. Samples treated at temperatures above 900° C were immediately transferred to a furnace at 900° C and held there for ½ h after holding at the higher temperature. All samples were then suitably cooled from 900° C to allow athermal transformation to bainite, as in cycle 4 in Fig. 1, thus reducing the

TABLE V Mechanical properties of 'fast' bainite in 3%Cr–Mo, cast 94544

Limit of proportionality tons/in²	Proof stress, % 0·05	0·1	0·2	0·5	Max. stress	True fracture stress	Elong., %	Red. in area, %	Transition temperature, °C Mean energy	50% cleaage	Av.
33·0	36·1	36·1	36·1	36·1	46·0	95·0	30	73	−66	−63	−65

TABLE VI Heat-treatment of 3%Cr–Mo, cast 91373, for athermal and isothermal bainite

Transformation product	Heat-treatment
Athermal bainite	½ h/900°C, AC to 600°C, rapidly FC to 500°C, ½ h/500°C (to equalize), FC to 300°C in 1 h (to transform) and AC + 48 h/650°C AC + 48 h/650°C AC
Isothermal bainite	½ h/900°C, AC to 600°C, rapidly FC to 380°C, 1½ h/380°C (to transform), and AC + 48 h/650°C AC + 48 h/650°C AC

heat-treatment variables between the differently austenitized samples. No evidence of overheating was detected in material austenitized at 1 250° C. The tempering treatments were then as follows:

(*a*) 48 h/650° C AC + 48 h/650° C AC (For an MS of 48 tons/in²),
or
(*b*) ½ h/650° C AC (For an MS of 67 tons/in²).

The austenite grain sizes so obtained are given in Table X. The mechanical properties corresponding to these different austenite grain size values are listed in Table XI.

In Tables XI*a* and *b*, the trend is for the average transition temperature to increase with the average austenite grain size. This is illustrated in Figs. 14*a* and *b*, respectively, the relationship in Fig. 14*a*, being roughly linear. The dotted line in Fig. 14*b* has been drawn assuming that a similar linear relationship obtains at a tensile level of about 67 tons/in² as at 48 tons/in². The slopes of these two lines are about 15° and 13° C for each ASTM number.

There would seem to be justification for assuming that transition temperature varies directly with parent austenite grain size over the range 48–67 tons/in² tensile strength, an increase in austenite grain size of one ASTM number causing an average increase in transition temperature of 14° C.

Something should be said about the use of temperatures up to 1 250° C to obtain the larger parent austenite grain sizes in the 3%Cr–Mo steel, in so far as such temperatures might have had effects other than that of simple grain growth. It is, of course, well known that overheating is one such danger, but no definite signs of this were found. In addition, as the parent austenite grain size was related roughly linearly to both austenitizing temperature and transition temperature, any effect which the austenitizing temperature had on transition temperature other than the indirect one on austenite grain size, would appear to be progressive. This would seem to rule out any overheating effect since the latter would be expected to come into play only above about 1 250° C while the austenitizing temperatures actually used were in the range 900–1 250° C. In the absence of temper embrittling treatments, all 3%Cr–Mo samples treated at temperatures above 900° C gave cleavage fractures within the ductile–brittle range suggesting that they had suffered no adverse effects at the prior elevated temperatures.

Effect of tensile strength on transition temperature of material of coarse-grained parent austenite

Since the parent austenite grain size had such a marked effect on transition temperature for a constant strength, it was interesting to know whether the transition temperatures of materials of coarse- and fine-grained parent austenite were similarly affected by variation in tensile strength. Accordingly, a series of samples of 3%Cr–Mo steel, from cast 94544, was austenitized at 1 175° and 900° C (to give a parent austenite grain size of ASTM3) as in the previous section, athermally transformed to bainite, and tempered to give tensile strengths varying from about 37 to 67 tons/in². The tempering treatments and mechanical properties so obtained are given in Table XII.

The average transition temperatures in Table XII are plotted as a function of tensile strength in Fig. 13*c*. The relationship observed in Fig. 13*c*, is similar to that in Figs. 13*a* and *b*, the point of inversion now occurring at about 41 tons/in². The slope of the major linear portion of Fig. 13*c*, is about 3·2 °C/ton/in².

Correlation between parent austenite and ferrite grain size

The fact that for 3%Cr–Mo steel a variation in austenite grain size by one ASTM number caused an average variation in transition temperature by 14° C, while for several low-alloy steels a variation in ferrite grain size by one ASTM number causes a variation in transition temperature of 13·4° C, the latter value being the average of five results quoted previously from the literature, at first suggested that the grain size of the ferrite formed in 3%Cr–Mo steel was roughly proportional to that of its parent austenite. While microscopic examination showed that the bainitic laths formed in 3%Cr–Mo steel were somewhat coarser with increasing parent austenite grain size, they were not in direct proportion. This implied that in this steel either the effect of ferrite grain size on transition temperature was much greater than that reported for other steels, or that there was some sort of co-operative effect between the ferrite grains formed from one parent austenite grain so that several small grains were behaving like one larger one. Some evidence for the latter view was obtained from a

TABLE VII Mechanical properties of 3%Cr–Mo, cast 91373, for athermal and isothermal bainite

Transformation product	Limit of proportionality	Proof stress %				Max. stress	True fracture stress	Elong., %	Red. in area, %	Transition temp., °C		
		0·05	0·1	0·2	0·5					Mean energy	50% cleavage	Av.
	tons/in²											
Athermal bainite	26·3	32·8	32·8	32·8	32·8	43·1	95·5	32·5	65·0	−80	−77	−79
Isothermal bainite	27·0	33·3	33·5	33·5	33·5	43·3	96·2	32·0	65·6	−93	−92	−93

TABLE VIII Transition temperatures and other relevant data for various steels

Transformation product	En 19			En 20			En 21			En 25			En 40B			5%Cr–Mo		
	GS	MS	TT	GS	MS	TT	GS	MS	TT	GS	MS	TT	GS	MS	TT	GS	MS	TT
Pearlite	6	48·0	73	6	46·6	97	9·5	41·1	2	...	...	...	7	44·8	47	7·5	40·4	32
Bainite	...	...	...	...	...	...	9·5	42·4	−17	7·5	45·2	14	7	44·6	−81	7·5	40·5	−11
Martensite	6	38·5	−40	6	42·4	−44	9·5	44·7	−81	7·5	46·2	−95	7	44·2	−112	7·5	43·5	−47

* Symbols GS, MS, and TT indicate austenite ASTM grain size no., maximum stress (tons in²), and average transition temperature (°C), respectively

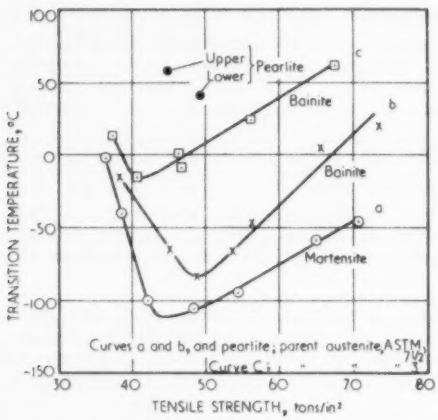
study of the fully brittle impact fractures of tempered athermal bainitic structures formed from coarse-grained austenite and quenched from the tempering temperature of 650° C. This work suggested that many ferrite grains formed from the one parent austenite grain might have related orientations and, therefore, would respond similarly to an overall applied stress. Thus, Fig. 15 shows the cleavage facets of the paler etching grains to lie parallel to one another, but to be inclined to the facets of the darker etching grains, these facets likewise being parallel to one another. Under certain conditions of heat-treatment, one large austenite grain can then be considered as producing either many small ferrite grains or a few large but 'partitioned' ones. The coarser the parent austenite grain, the more small ferrite grains will be formed but the greater will be the co-operative effect.

Ferrite grain size of the several transformation products

As it was very difficult to distinguish microscopically the ferrite grain size of tempered martensitic or bainitic structures, recourse was had to X-ray diffraction examination by the standard back reflection technique. It was found for 3%Cr–Mo and the other steels that for a fixed parent austenite grain size and tensile strength (about 45 tons/in²), the ferrite grain size was very much finer for tempered martensitic or bainitic structures than for pearlitic ones. Visual examination of these X-ray diffraction photographs showed little difference between martensite and bainite. Figures 16, 17, and 18 show typical back reflection photographs for upper pearlite, lower pearlite, and bainite in 3%Cr–Mo steel, cast 94544; all the samples having been austenitized at 900° C and tempered, as necessary, to a tensile strength of about 45 tons/in². The lower pearlite has a finer ferrite grain size than that of the upper pearlite in keeping with the former's lower transition temperature, whilst the bainite has the finest grain size of the three. Hyam and Nutting[25] found the ferrite grain size in their martensitic plain carbon steels, which had been tempered at 650° or 700° C, to be about 2μ, while

TABLE IX Tempering treatments and mechanical properties of 3%Cr–Mo steel, cast 94544, for various levels of tensile strength

Tempering treatment	Limit of proportionality	Yield point or proof stress				Max. stress	True fracture stress	Elong., %	Red. in Area, %	Transition temperature, °C		
	Tons in²									Mean energy	50% cleavage	Average
Martensitic series		***UYP***		***LYP***								
672 h/700° C WQ + 504 h/700° C WQ	28·8	28·8		26·6		36·4	76·0	37·5	69	...	−2	−2
64 h/740° C WQ + 64 h/740° C WQ	32·0	32·0		30·0		38·6	87·5	38	73·5	...	−40	−40
6 h/740° C WQ + 6 h/740° C WQ	29·0	33·5		32·8		42·1	98·6	35	76·5	...	−100	−100
		0·05%	0·1%	0·2%	0·5%							
4 h/720° C AC	33·0	38·8	38·8	38·8	38·8	48·4	105·7	32	75	−105	−107	−106
8 h/650° C AC	36·5	42·5	43·6	44·7	45·0	54·3	110·0	28	73·5	−93	−94	−94
1½ h/650° C AC	38·0	49·5	51·6	53·1	56·0	65·1	126·0	26	71	−52	−63	−58
12 min/650° C AC	43·0	54·9	57·3	59·7	62·0	70·8	127·0	23	68·5	−43	−49	−46
Bainitic series		***UYP***		***LYP***								
64 h/740° C WQ	31·7	31·7		28·7		38·3	84·5	37·5	72	...	−15	−15
		0·05%	0·1%	0·2%	0·5%							
48 h/650° C AC + 48 h/650° C AC	30·0	34·1	34·3	34·7	35·0	45·2	95·0	30	73	−65	−64	−65
16 h/650° C AC + 24 h/650° C AC	32·0	38·1	38·9	39·0	39·0	48·8	100·0	30·5	73	−84	−84	−84
8 h/650° C AC	37·0	42·5	43·2	44·2	45·0	53·7	109·0	28	73	−64	−65	−65
3 h/650° C AC + 1 h/650° C AC	37·0	45·2	46·0	46·6	47·2	56·3	107·5	25	71	−46	−48	−47
¼ h/650° C AC	40·0	51·7	53·7	55·1	58·0	65·9	111·7	22	65	10	−2	4
9 min/650° C AC	42·0	57·2	60·0	63·0	66·0	73·5	123·0	22	62·5	27	12	20



13 *Relationship between transition temperature and tensile strength, (a) for martensite, (b) and (c) for bainite. Note: (a) and (b) formed from austenite of ASTM7·5, (c) from ASTM3*

Irvine and Pickering[26] observed a similar size in low-carbon bainitic steels, as transformed. The grain size indicated by Fig. 18 is of the order found by these other workers. Such a grain size is equivalent to about ASTM15. Metallographic work suggested a value of ASTM14. For the present purpose, the average value of ASTM14·5 will be used.

Comparison with X-ray diffraction standards showed the grain size of the upper pearlite to be about ASTM8. Taking a difference of ferrite grain size of one ASTM number as equivalent to 13·4° C, the difference of the 6·5 ASTM numbers between pearlite and tempered bainite is equivalent to 87° C. The actual difference in transition temperature observed was 123° C. The fair agreement between these two values suggests that the lower transition temperature of bainite (or martensite) compared with that of pearlite is primarily due to the former's finer ferrite grain size.

The inversion in the transition temperature/tensile strength relationship

The increase in transition temperature in 3%Cr–Mo steel as the tensile strength decreases below a certain critical value would appear to be similar to what has been observed by several groups of workers[27-30] in the USA, and called 'upper nose embrittlement.' This is distinct from temper embrittlement, since upper nose embrittlement occurs at higher tempering temperatures and up to Ac_1, but its cause has not yet been established. Two explanations have been offered: (*a*) ferrite grain growth, and (*b*) carbide agglomeration.[31] Evidence has been obtained in the present investigation which supports the former explanation. This evidence was threefold:

(i) X-ray diffraction examination by the back reflection technique indicated an increase in ferrite grain size as between the bainitic sample tempered to a tensile strength of 48·8 tons/in² and that tempered to a tensile strength of 38·3 tons/in². Both those samples are represented in Fig. 13*b*

(ii) metallographic examination carried out by optical microscopy at a magnification of × 2 000, of the samples represented in Fig. 13*b*, tempered to tensile strengths of 38·3 and 45·2 tons/in² allowed some estimate to be made of their respective ferrite grain sizes. The latter corresponded to ASTM10 and 14 respectively. Some idea of these grain sizes can be obtained from Figs. 19 and 20. Taking a variation in ferrite grain size by one ASTM number as being equivalent to 13·4° C variation in transition temperature (this value being derived as previously), the difference of 4 ASTM numbers is equivalent to 54° C difference in transition temperature. The actual experimental difference was 50° C

(iii) if ferrite grain growth were the cause of the effect, initially coarser grained material should show a smaller effect than that initially finer grained. Comparison of Figs. 13*b* and *c* shows that this was the case.

Estimation by optical microscopy of the ferrite grain size of the samples of 38·6, 38·3, and 37·4 tons/in² tensile strength in Figs. 13*a*, *b*, and *c* respectively, indicated differences which were roughly in keeping with their differences in transition temperature.

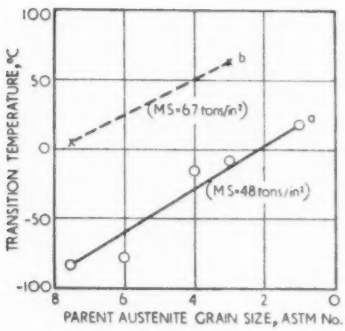
Finally, optical microscopic examination of longitudinal sections taken through the fully brittle

TABLE X Effect of temperature on austenitic grain size

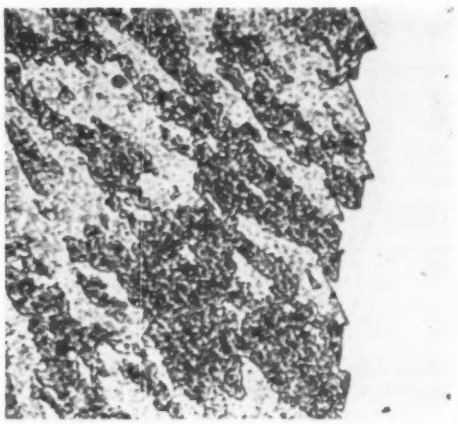
Austenitizing temperature, °C	900	1 000	1 100	1 175	1 250
Austenite ASTM grain size no.	7-8	5-3	3-5	2-4	0-2

TABLE XI Mechanical properties of 3%Cr–Mo, cast 94544, for different prior austenite grain-size values

Average Austenite ASTM grain size no.	Limit of proportionality	Proof stress, %			Max. stress	True fracture stress	Elong., %	Red. in area, %	Transition temperature, °C		
		0·05	0·1	0·2	0·5				Mean energy	50% cleavage	Average
	tons/in²										
(a) For an MS of 48 tons in²											
7	32·0	38·1	38·9	39·0	39·0	48·8	100·0	30·5	73	− 84	− 84	− 84
6	31·0	35·0	35·3	35·9	36·5	46·4	96·0	30·5	73·5	− 80	− 75	− 78
4	32·0	37·0	37·8	38·3	39·3	48·1	98·0	31	72·5	− 13	− 18	− 16
3	28·0	36·0	36·5	37·2	38·0	46·7	96·2	29	73	− 6	− 10	− 8
1	32·0	38·4	39·0	39·5	40·0	48·7	91·0	26·5	66·5	24	12	18
(b) For an MS of 67 tons in²											
7½	40·0	51·7	53·7	55·1	58·0	65·9	111·7	22	65	10	− 2	4
3	42·0	52·8	54·7	56·6	59·0	67·2	103·0	21	54·5	70	56	36



14 *Relationship between transition temperature and parent austenite grain size for tensile strengths of (a) 48 tons/in², (b) 67 tons/in²*



15 *Cleavage impact fracture of 3%Cr–Mo steel rotor core no.36 treated for 1h at 650° C, WQ* × 1000

impact fractures of the latter three samples, showed the fractures to be predominantly by cleavage of the ferrite grains. Figure 19 is representative. Taken together, all these observations confirm that the embrittlement obtained on prolonged tempering within the range 650–740° C is a phenomenon distinct from temper embrittlement and is probably largely due to ferrite grain growth. (Ac_1 for this steel, cast 94544, was determined as 775° ± 5° C.)

Effect of temper embrittlement on transition temperature

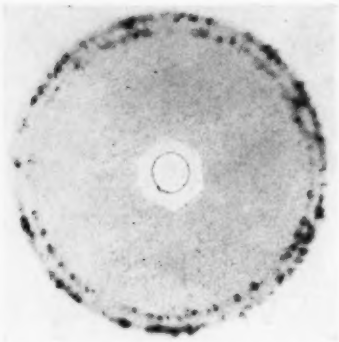
It is well known that certain low-alloy steels which have either been slowly cooled in the temperature range 650° to about 350° C, or have been held for some time in this range, become temper embrittled. This embrittlement is manifested by an increase in transition temperature and by a change from transcrystalline fracture of the ferrite grains to fracture at the prior austenite grain boundaries in impact tests carried out within or below the ductile–brittle transition temperature range.

When this work began, it was believed that 3%Cr–Mo steel had only a slight susceptibility to temper embrittlement. This belief had probably arisen through carrying out impact tests on bar material only at room temperature (RT), and as such material can have a transition temperature well below RT when in the martensitic or bainitic condition, any temper embrittlement induced in it might not be detected at RT. Detailed investigation showed, however, that the brittle fractures of impact test pieces from slowly cooled 3%Cr–Mo forgings tended to follow in part the prior austenite grain boundaries and, moreover, retreatment of test material from such forgings for 1 h/650° C, WQ, lowered the transition temperature by up to about 65° C. Both these observations suggested that the susceptibility to temper embrittlement was greater than expected.

This then raised the question as to whether the correlations established between transition temperature and the several variables studied, also applied in the presence of temper embrittlement. The effects of microstructure (i.e. transformation product), tensile level, and grain size, all in the presence of temper embrittlement, were, therefore, re-investigated. It can be said that in general the same relationships apply, save that the levels of transition temperature are all raised as a result of the temper-embrittlement. Thus, for the same parent austenite grain size of ASTM7·5 and tensile level of 45 tons/in², pearlitic, bainitic, and martensitic structures were found to be equally susceptible to temper embrittlement, their

TABLE XII Tempering treatments and mechanical properties of 3%Cr–Mo steel, cast 94544, of prior coarse-grained austenite

Tempering treatment	Limit of proportionality tons/in²	Yield point or proof stress				Max. stress	True fracture stress	Elong., %	Red. in area, %	Transition temperature, °C		
										Mean energy	50% cleavage	Average
64 h 740°C WQ + 64 h 740°C WQ	22·0	*UYP* 25·6		*LYP* 25·4		37·4	82·5	37·5	72	...	13	13
48 h 700°C WQ + 48 h 700°C WQ	21·3	0·05% 28·5	0·1% 29·2	0·2% 29·7	0·5% 30·1	40·6	88·0	33·5	73·5	...	− 17	− 17
48 h 650°C WQ + 48 h 650°C WQ	29·0	34·8	35·5	36·6	37·6	46·2	94·0	28·5	72·5	...	1	1
48 h 650°C WQ + 48 h 650°C WQ	28·0	36·0	36·5	37·2	38·0	46·7	96·2	29	73	− 6	− 10	− 8
3 h 650°C WQ + 1 h 650°C WQ	35·0	44·0	45·2	46·1	47·1	56·0	100·7	25	68	...	25	25
¼ h 650°C AC	42·0	52·8	54·7	56·6	59·0	67·2	103·0	21	54·5	70	56	63



16 *X-ray diffraction reflection photograph for* 3%Cr–Mo *steel, cast 94544, showing upper pearlite*

transition temperatures being raised by 59°, 60°, and 61° C respectively.

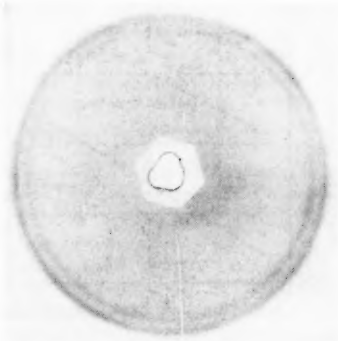
There was a suggestion that the susceptibility to temper embrittlement decreased with increasing parent austenite grain size but this may have been due to the very high temperatures used to obtain the larger austenite grain sizes. Further work would be required to establish this.

The susceptibility to temper embrittlement also raised the question as to whether air cooling instead of water quenching the $\frac{3}{4}$-in. dia. bar sections from the tempering temperature of 650° C in all the previous work had affected the transition temperature. Two further series of samples in the martensitic and two in the pearlitic condition were prepared. One series was water quenched and one air cooled from the tempering temperature of 650° C and their transition temperatures determined. Water quenching gave transition temperatures 7° C lower and 2° C higher than air cooling for the martensitic and pearlitic microstructures respectively. As these values are within the estimated experimental error of about ± 10° C, they are not significant and suggest that with the 3%Cr–Mo steel used for these experiments, air cooling from 650° C has not significantly affected the transition temperature of $\frac{3}{4}$-in. dia. bar material. Air cooling had originally been adopted to avoid any possible effect on the transition temperature of residual macrostresses resulting from water quenching from 650° C.

Effect of carbon content on transition temperature of 3%Cr–Mo steel

The effect will now be considered of variation in

17 *As Fig.16, showing lower pearlite*



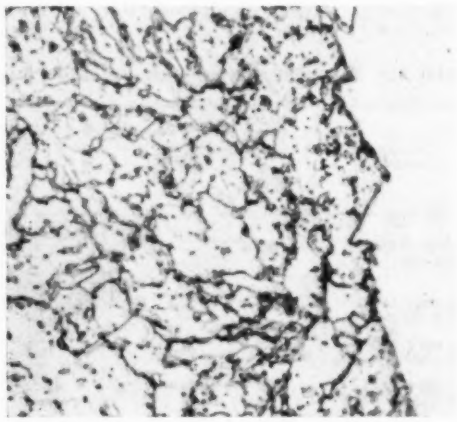
18 *As Fig.15, showing bainite, tempered for 96 h at 650°C*

composition, particularly in carbon content, between casts of the same nominal type or within the one forging owing to segregation. While the latter will be of slight effect in the bar materials studied, it may be important when considering the properties of material taken from the core of a large rotor forging. As it was found that the carbon content of 3%Cr–Mo forgings could vary by ± 0·05% as between the core and the cast analysis, and by ± 0·04% within the core itself, the effect of variation in carbon content was investigated.

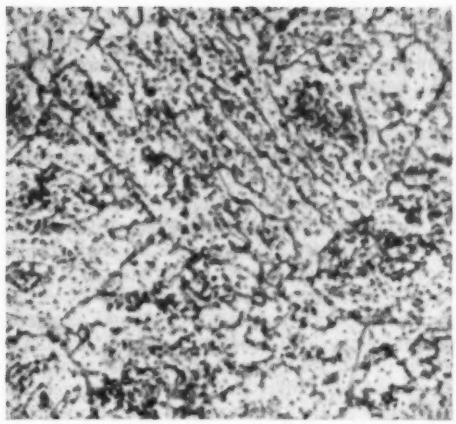
Bar material (3%Cr–Mo) from casts 90706, 91373, 86519, and 88501 containing 0·18, 0·25, 0·26, and 0·30%C respectively, were heat-treated to give tempered martensitic, bainitic, and pearlitic microstructures of about 45 tons/in² tensile strength. Details of the heat-treatments and mechanical properties so obtained are given in Tables XIII and XIV respectively.

The parent austenite grain sizes of these casts after the treatments detailed in Table XIII, were as follows:

Cast no.	90706	91373	86519	88501
Austenite ASTM grain size no.	7–8	8–10	7	8–9



19 *Photomicrograph of* 3%Cr–Mo *steel, cast 94544, showing cleavage impact fracture of bainite, tempered for 128 h/740°C* × 2000



20 *As Fig.19, showing fine ferrite grain size of bainite tempered for 96h at 650°C* × 2000

The final corrected average transition temperatures in Table XIV are plotted as a function of carbon content in Fig. 21. This shows that for all three microstructures, the effect of carbon in the range 0·18–0·30% is to raise the transition temperature, the effect tending to be greater at the higher end of the range. The average increase in transition temperature for an increase in carbon content of 0·01% is 4·8, 5·0, and 5·8° C for pearlite, bainite, and martensite, respectively.

It is believed that any cast-to-cast or local variation in other alloying elements will have less effect than that of carbon on transition temperature.

The effect of composition, *per se*, on transition temperature is now being studied. The results to date suggest that the major effect is an indirect one in determining the ferrite grain size.

DISCUSSION

Of the several factors found to control transition temperature in the present work, perhaps the most important is ferrite grain size. The latter is itself determined by three factors, (*a*) parent austenite grain size, (*b*) austenite transformation temperature, and (*c*) conditions of tempering. The ferrite grain size was found to be finer as the parent austenite grain size became finer. This was suggested by Burns and Judge[20] and demonstrated by Owen *et al.*[18] The ferrite grain size has been shown by X-ray diffraction examination in the present investigation to be finer the lower the austenite transformation temperature, a difference of about 7 ASTM numbers having been found between the ferrite grain size in pearlite and in tempered bainite in a 3%Cr–Mo steel. Prolonged tempering at temperatures relatively near Ac_1 can, on the other hand, affect the ferrite grain size by causing grain growth.

The decrease in transition temperature with decreasing ferrite grain size observed generally throughout this work is, at least qualitatively, in keeping with current theory.[32, 33] In the present work it was found that the grain size of the ferrite could be measured with less certainty than that of the parent austenite. Where estimates of ferrite grain size were made, a difference of one ASTM number was found to be equivalent to about 13° and 19° C difference in transition temperature. The former figure was

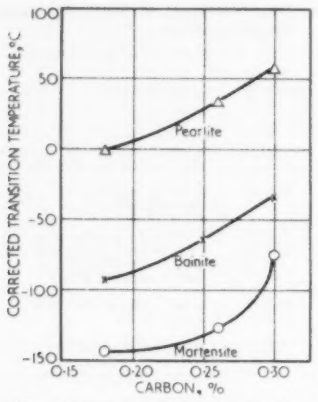
TABLE XIII Heat-treatment of 3%Cr–Mo casts of various carbon contents

Transformation product	Carbon content, %	Heat-treatment
Pearlite	0·18 and 0·30	½ h 900° C, rapidly FC to 700° C, 1½ h 700° C (to transform), and AC + ½ h 700° C AC
Pearlite	0·26	½ h 900° C, rapidly FC to 700° C, 1½ h 700° C (to transform), and AC + ½ h 700° C AC
Bainite	0·18, 0·25 and 0·30	½ h 900° C, AC to 600° C, rapidly FC to 500° C, 15 min 500° C (to equalize), FC to 300° C in 1 h (to transform), and AC + 48 h 650° C AC + 48 h 650° C AC
Martensite	0·18 and 0·26	½ h 900° C OQ + 4 h 720° C AC
Martensite	0·30	½ h 900° C OQ + 4 h 750° C AC

TABLE XIV Mechanical properties of 3%Cr–Mo casts of various carbon contents

Transformation product	Carbon, %	Limit of proportionality	Proof stress, %				Max. stress	True fracture stress	Elong., %	Red. in area, %	Transition temperature, °C			
		tons in⁻²	0·05	0·1	0·2	0·5					Mean energy	50% cleavage	Average	Corrected*
Pearlite	0·18	17·0	19·5	19·5	19·5	19·5	39·3	77·3	33·5	66·5	0	11	6	−1
,,	0·26	19·0	22·0	22·0	22·0	22·0	44·8	81·0	30·5	62	43	50	47	33
,,	0·30	13·5	21·2	21·5	21·5	21·5	46·8	76·7	28	53	50	50	50	57
Bainite	0·18	25·5	31·8	32·3	32·7	33·7	43·0	95·5	33	76	−87	−87	−87	−94
,,	0·25	26·3	32·8	32·8	32·8	32·8	43·1	95·5	32·5	65	−80	−77	−79	−65
,,	0·30	30·0	34·0	34·0	34·0	34·0	45·1	93·7	32	73	−41	−41	−41	−34
Martensite	0·18	25·0	30·2	30·7	31·3	32·0	42·2	102·0	35	78·5	−137	−136	−137	−144
,,	0·26	31·0	34·4	34·4	34·4	34·4	44·2	112·0	35·2	78·5	−114	−109	−112	−126
,,	0·30	30·5	UYP 35·4		LYP 34·6		44·1	100·8	34	75·5	−77	−87	−82	−75

* The average transition temperature has been corrected in the last column for a parent-austenite grain size of ASTM8 so that the effect of carbon can be determined independently of this other variable. It has been assumed that the same correction factor for parent-austenite grain size as was derived for bainite can be applied to pearlite and martensite



21 *Relationship between transition temperature and carbon content in 3%Cr–Mo steels, for microstructures of tempered martensite, bainite, and pearlite*

based on grain sizes determined by optical microscopy in heavily tempered bainitic microstructures, while the value of 19° C was based on grain sizes determined by X-ray diffraction examination in samples of pearlitic and tempered bainitic microstructures.

A second major factor affecting transition temperature was found to be tensile strength. This relationship is more empirical than fundamental. However, if the average transition temperatures for tempered martensite and bainite in Tables IX and XII are plotted as a function of yield stress (LYP) or 0·5% proof stress, since in most cases no sharp yield point was obtained on testing at room temperature, the relationships obtained are similar to those obtained taking nominal tensile strength as the parameter. Similar relationships are also obtained on plotting transition temperature as a function of true fracture stress. Ignoring the inversion effect at low tensile strengths, the relationship between transition temperature and yield or 0·5% proof stress is also in keeping with current theory.[32, 33] In the present work, a variation of 1 ton/in² in 0·5% proof stress caused a variation in transition temperature of 2·8–4·2° C.

Cottrell[33] has given a theoretical treatment of the changes in transition temperature of mild steel with grain size and yield point. According to his calculations, the impact transition temperature should be increased by 33° C when the grain size is doubled, i.e. 16½° C increase in transition temperature for unit change in ASTM grain size. Increasing the yield strength by 1 ton/in² should raise the transition temperature by about 6° C.

However, several uncertainties arise when attempting to apply Cottrell's theory to the present work on 3%Cr–Mo steel. In most cases in this work it was possible to measure accurately only the austenite grain size; the relation between austenite grain size and ferrite grain size is uncertain, even when considering only one transformation product such as bainite. In addition the theory may need modification for the case where, in contrast to mild steel, there is no definite yield point. It is perhaps somewhat early to attempt a quantitative explanation of the present experimental results on an alloy steel such as 3%Cr–Mo.

With regard to the inversion in the transition temperature/tensile or yield stress relationship, it is suggested that the effect arises only through the change of grain size resulting from prolonged tempering. At tensile levels above that at the point of inversion, the ferrite grain size is considered to remain largely unaffected by the tempering treatments, the latter merely resulting in a relief of microstresses. Transition temperature is then mainly a function of yield stress for a virtually constant ferrite grain size. At the lower tensile levels, however, prolonged tempering causes ferrite grain growth so that transition temperature is now affected by ferrite grain size and yield stress, the former predominating.

The present work points to a rational explanation for the difference in transition temperature between two steels of different composition. Assuming neither has been temper embrittled and the comparison is made at the same tensile level, the principal distinguishing factor will be ferrite grain size. This will be determined by the parent austenite grain size, the nature of the austenite transformation product, and possibly by tempering conditions. Thus, a steel having a tempered martensitic or bainitic structure will probably have a lower transition temperature than a steel with a pearlitic structure; hence the superiority of 3%Cr–Mo steel over, for example, a plain carbon or 1%Ni steel. The question of composition, however, is now being studied further.

The final main factor affecting transition temperature is that of temper embrittlement. This is a complication in that it changes the mode of brittle fracture from cleavage of the ferrite grains to a tendency to intergranular fracture at the prior austenite grain boundaries. In addition, not all qualities of steel are equally susceptible. Its presence must be watched for, since by raising the transition temperature by perhaps as much as 65° C, as for 3%Cr–Mo steel, it may mask the effect of other variables.

Summary of Part 1

A systematic study of the factors affecting the transition temperature of 3%Cr–Mo steel in bar form has given the following results:

(1) The lower the austenite transformation temperature the lower the transition temperature, a greater difference being obtained between pearlite and bainite than between bainite and martensite, other things being equal. Similar results were obtained with several other low-alloy steels.

(2) The lower transition temperature of bainite or martensite compared with that of pearlite is probably primarily due to the former's finer ferrite grain size.

(3) The finer the parent austenite grain size, the lower the transition temperature, a change by one ASTM number being equivalent to 14° C for tempered bainitic structures.

(4) Down to a critical value, the lower the tensile strength, the lower the transition temperature, a change by 1 ton/in² being equivalent to 3° and 5° C for tempered martensitic and bainitic structures respectively, for a parent austenite grain size of ASTM7·5. Coarsening the parent austenite grain size from ASTM7·5 to 3 lowered the correction factor for tempered bainitic structures from 5° to 3·2° C.

Below the critical value, an inversion occurred such that further decrease in tensile strength was accompanied by an increase in transition temperature. This increase was due to ferrite grain growth caused by prolonged tempering.

(5) Temper embrittlement was found to be a more significant factor in 3%Cr–Mo steel than had been anticipated. Its presence could mask effects detailed in items (1)–(4).

(6) The lower the carbon content, the lower the transition temperature, a change by 0·01% in carbon content being equivalent to 4·8°, 5·0°, and 5·8° C for pearlitic, tempered bainitic, and tempered martensitic structures respectively.

TABLE XV Dimensions and analyses of forgings

Type of steel	Forging no.	Body dia., in.	Analysis, wt-% C	Si	Mn	S	P	Cr	Ni	Mo	V	N
Rotor shafts												
Carbon	1	36	0·36	0·21	0·76	0·021	0·023	0·28	0·37	...	...	
	2	36	0·34	0·23	0·70	0·026	0·022	0·27	0·38	...	...	0·004
	3	36	0·36	0·26	0·80	0·025	0·025	0·26	0·39	...	...	
	4	36	0·35	0·25	0·77	0·025	0·024	0·27	0·39	...	...	
	5	33	0·38	0·29	0·80	0·019	0·022	0·24	0·35	...	...	
	6	41	0·38	0·29	0·80	0·019	0·022	0·24	0·35	...	...	
	7	31	0·39	0·23	0·74	0·020	0·024	0·40	0·40	...	...	
	8	39	0·34	0·25	0·84	0·024	0·025	0·29	0·39	...	...	
C Mo	9	43	0·32	0·25	0·70	0·035	0·022	0·25	0·54	0·70	...	
	10	37	0·32	0·24	0·76	0·033	0·028	0·31	0·57	0·65	...	
	11	40	0·33	0·25	0·81	0·028	0·030	0·20	0·47	0·61	...	
	12	40	0·33	0·25	0·78	0·024	0·024	0·23	0·59	0·63	...	
	13	32	0·32	0·22	0·72	0·017	0·024	0·23	0·51	0·57	...	0·005
1%Ni	14	35	0·39	0·28	0·85	0·027	0·024	0·24	1·12	0·06	...	
	15	35	0·39	0·28	0·85	0·027	0·024	0·24	1·12	0·06	...	
	16	35	0·36	0·25	0·80	0·030	0·021	0·08	1·12	0·03	...	
	17	47	0·38	0·21	0·80	0·019	0·023	0·27	1·14	0·06	...	
	18	47	0·38	0·21	0·80	0·019	0·023	0·27	1·14	0·06	...	
	19	47	0·38	0·20	0·77	0·020	0·024	0·26	1·10	0·03	...	
	20	47	0·38	0·20	0·77	0·020	0·024	0·26	1·10	0·03	...	
	21	35	0·40	0·24	0·82	0·026	0·023	0·16	1·12	0·08	...	0·004
Ni Cr Mo	22	39	0·26	0·25	0·54	0·021	0·027	0·49	2·41	0·42	...	
	23	42	0·25	0·23	0·55	0·028	0·021	0·51	2·36	0·34	...	
	24	39	0·23	0·25	0·59	0·020	0·021	0·47	2·26	0·41	...	
	25	42	0·23	0·19	0·47	0·030	0·022	0·50	2·28	0·40	...	
	26	37	0·23	0·19	0·54	0·024	0·022	0·53	2·34	0·39	...	0·004
Ni V	27	39	0·43	0·20	0·71	0·024	0·022	0·07	2·43	...	0·13	
	28	39	0·40	0·28	0·76	0·026	0·018	0·25	2·39	...	0·16	0·006
3%Cr Mo	29	57	0·33	0·25	0·43	0·030	0·022	3·28	0·17	0·59	...	0·009
	30	39	0·27	0·30	0·63	0·013	0·020	3·22	0·15	0·59	...	0·005
	31	37	0·21	0·20	0·46	0·030	0·023	3·29	0·12	0·57	...	0·006
	32	55	0·25	0·20	0·64	0·024	0·020	3·23	0·16	0·59	...	0·007
	33	57	0·28	0·22	0·58	0·022	0·026	3·26	0·15	0·57	...	0·007
	34	43	0·25	0·20	0·61	0·019	0·025	3·30	0·12	0·56	...	0·006
	35	50	0·29	0·22	0·55	0·024	0·021	3·35	0·10	0·59	...	0·008
	36	40	0·28	0·21	0·60	0·022	0·025	3·41	0·14	0·52	...	0·007
	37	41	0·32	0·20	0·56	0·023	0·024	3·25	0·17	0·57	...	0·008
	38	36	0·24	0·25	0·52	0·025	0·021	3·32	0·14	0·58	...	0·006
	39	41	0·26	0·24	0·63	0·023	0·025	3·45	0·16	0·56	...	0·008
	40	42	0·28	0·21	0·66	0·027	0·028	3·31	0·25	0·59	...	0·007
	41	46	0·28	0·20	0·45	0·026	0·023	3·00	0·18	0·59	...	0·007
	42	38	0·25	0·23	0·58	0·035	0·026	3·33	0·15	0·59	...	0·006
Turbine wheels												
3%Cr–Mo		Hub thickness, in.										
	43	16½	0·35	0·34	0·73	0·006	0·015	3·16	0·19	0·67	...	0·013
	44	16½	0·34	0·34	0·73	0·006	0·015	3·16	0·19	0·67	...	0·013
	45	8½	0·27	0·14	0·54	0·004	0·013	3·05	0·20	0·48	...	0·012
	46	8	0·25	0·14	0·59	0·006	0·014	3·30	0·20	0·45	...	0·011
	47	10½	0·26	0·23	0·62	0·008	0·016	3·26	0·15	0·62	...	0·015
	48	10½	0·24	0·33	0·57	0·005	0·012	3·23	0·16	0·62	...	0·013
	49	12½	0·26	0·30	0·64	0·008	0·019	3·19	0·16	0·49	...	0·015
	50	8	0·25	0·34	0·57	0·010	0·012	3·24	0·36	0·47	...	0·013
	51	16	0·26	0·33	0·63	0·007	0·010	3·34	0·15	0·45	...	0·014
	52	11½	0·26	0·35	0·62	0·007	0·010	3·55	0·15	0·46	...	0·011
	53	13	0·31	0·25	0·77	0·014	0·013	3·36	0·17	0·73	...	0·014
	54	10	0·26	0·25	0·60	0·014	0·018	3·96	0·13	0·43	...	0·013
	55	10	0·27	0·25	0·60	0·014	0·018	3·96	0·13	0·43	...	0·015
	56	7½	0·32	0·31	0·68	0·012	0·008	2·31	0·15	0·53	...	0·012
	57	7½	0·31	0·31	0·68	0·012	0·008	2·31	0·15	0·53	...	0·011
	58	10	0·30	0·20	0·75	0·008	0·017	3·36	0·14	0·63	...	0·012
	59	12½	0·35	0·20	0·75	0·008	0·017	3·36	0·14	0·63	...	0·014
	60	12½	0·36	0·20	0·75	0·008	0·017	3·36	0·14	0·63	...	0·014
	61	7	0·28	0·25	0·58	0·005	0·011	3·38	0·31	0·49	...	0·013
	62	7½	0·26	0·34	0·59	0·010	0·018	3·39	0·14	0·50	...	0·012
	63	10	0·24	0·35	0·52	0·011	0·010	3·51	0·23	0·46	...	0·015
	64	7½	0·27	0·29	0·61	0·007	0·015	3·39	0·25	0·50	...	0·014
	65	8	0·26	0·22	0·55	0·009	0·014	3·25	0·13	0·66	...	0·013
	66	5½	0·28	0·34	0·66	0·007	0·014	2·34	0·36	0·53	...	0·010
	67	6½	0·26	0·25	0·60	0·010	0·013	3·37	0·28	0·50	...	0·013

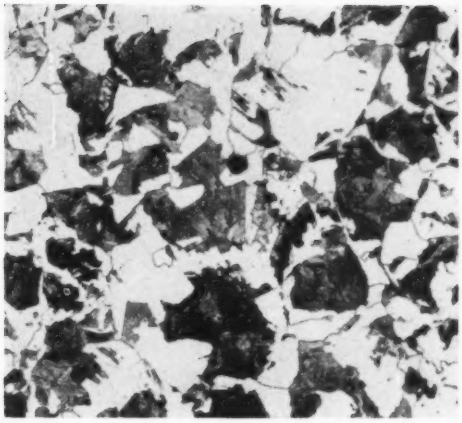
PART II: THE TRANSITION TEMPERATURE OF MATERIAL FROM FORGINGS

Description of forgings

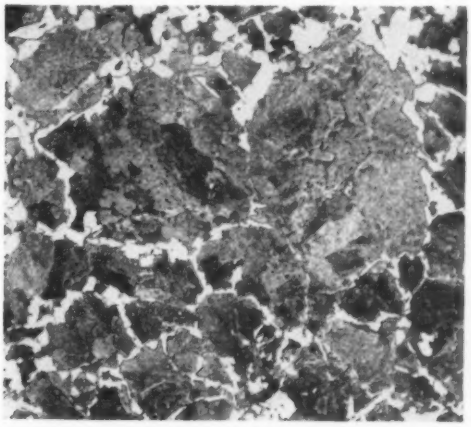
The forgings investigated were rotor shafts and turbine wheels made by normal production methods for use in electric power generating equipment. Acid open-hearth steel was used for the rotor shafts and basic electric-arc steel for the turbine wheels. The chemical compositions of the various forgings are given in Table XV; the carbon and nitrogen contents of the 3%Cr–Mo steels were determined on the actual test material, while all the other figures were obtained by analysis of a box test taken when the steel was cast. It was found that the carbon content of 3%Cr–Mo forgings could vary by ± 0·05% as between the

TABLE XVI Mechanical properties of forgings as works-treated

Type of steel	Forging no.	YP tons	MS in²	Elong., %	Red. in area, %	Parent Austenite grain size ASTM no.	Transition temperature, °C (a) 15 ft-lb	(b) Mean energy	(c) 50% cleavage	(d) Average of (b) and (c)	(e) (d) Corrected to ASTM3
Rotor shafts											
Carbon	1	17·0	35·0	25·5	43	2·3	− 6	35	50	42	35
	2	17·0	35·2	23	37	1·3	37	72	75	74	60
	3	16·4	35·0	30·5	47	1·2	12	60	54	57	36
	4	16·4	34·6	30	47	− 1 to + 1	13	62	53	57	15
	5	18·9	36·7	31·5	47	0·3	0	57	55	56	35
	6	19·6	39·2	19	40	1·3	33	85	88	87	73
	7	20·0	38·4	25·5	45	1·3	63	102	108	105	91
	8	20·7	39·9	27	47	2·3	30	87	86	86	79
C–Mo	9	25·6	38·4	23·5	43	1·3	52	106	100	103	89
	10	28·0	41·0	23·5	46	1·2	86	115	117	116	95
	11	28·0	40·6	23	47	− 1 to + 1	73	110	110	110	68
	12	27·0	39·8	24·5	48	1·2	50	105	105	105	84
	13	20·7	43·0	20·5	36	1·2	73	118	117	117	96
1% Ni	14	20·0	39·1	28	46	2·3	29	88	72	80	73
	15	21·0	41·3	24	45	2·3	34	80	79	79	72
	16	19·9	37·1	26	45	2·3	13	96	75	85	78
	17	20·8	39·2	15·5	23	1·3	22	63	80	72	58
	18	22·4	42·4	22·5	42	1·3	53	98	110	104	90
	19	18·2	36·2	20	51	1·3	31	58	87	73	59
	20	21·6	42·4	24·5	39	1·3	85	115	115	115	101
	21	20·7	34·2	21	33	2–4	28	72	73	73	73
Ni–Cr–Mo	22	39·6	47·2	19·5	48	3·6	58	110	108	109	130
	23	33·6	42·3	21	40	3·5	37	92	100	96	110
	24	26·8	37·0	22·5	38	1·3	3	67	66	66	52
	25	23·4	36·0	26·5	51	0·1	33	38	30	34	− 1
	26	27·8	38·2	28	57	3·5	− 12	28	40	34	48
Ni–V	27	32·6	47·0	21	44	6·7	30	67	62	64	113
	28	33·6	46·2	22·5	47	7	− 8	65	48	56	112
3%Cr–Mo	29	38·0	49·2	21	56	0·1	+15	64	80	72	37
	30	38·0	47·0	17·5	47	2·3	− 10	66	60	60	53
	31	34·0	43·8	23	65	1–2	− 38	37	25	31	10
	32	35·4	45·8	23	65	1·2	− 18	78	65	70	49
	33	38·0	48·6	16·5	43	1	+ 34	103	100	102	74
	34	33·6	43·0	23	68	1	− 12	57	35	46	18
	35	33·0	44·6	25	62	0–1	− 12	65	56	61	26
	36	42·0	51·0	17	45	0	+ 39	110	90	100	58
	37	36·3	47·8	23	59	1·2	− 5	53	55	54	33
	38	39·1	47·1	23	63·5	1·2	+ 3	73	60	66	45
	39	40·9	50·4	21	58	1·2	+ 21	105	85	95	74
	40	43·0	55·0	10	29	0·1	+ 27	120	105	112	77
	41	36·6	45·8	23	58	0·1	+ 17	72	67	70	35
	42	40·0	50·2	13·5	32	1·2	+ 10	76	55	65	44
Turbine wheels											
3%Cr–Mo	43	44·4	55·6	23·5	63	4–5	− 10	89	80	84	105
	44	46·4	56·2	22·6	58	4–5	− 5	87	65	76	97
	45	41·2	52·4	23·5	70	4–5	− 94	7	2	4	25
	46	42·0	52·8	25	70	4	− 52	7	4	7	21
	47	40·5	50·6	27	70	4·5	− 28	11	19	15	36
	48	39·6	49·6	26	70	6·7	− 40	12	12	12	61
	49	44·8	55·1	24	63	5	− 35	55	41	48	76
	50	42·0	52·2	25·5	72	4–5	− 74	16	12	14	35
	51	42·0	51·9	23	64	5·6	− 52	56	36	46	81
	52	42·6	52·6	25·5	66	5·6	− 57	52	44	48	83
	53	41·2	52·6	24	61	4·5	− 37	67	50	58	79
	54	43·5	52·7	25	68	3·6	− 19	40	47	43	64
	55	44·0	54·0	23	64	4·5	− 15	72	68	70	91
	56	42·3	53·5	24	65	6	− 80	− 22	− 10	− 16	26
	57	42·1	52·5	19·5	50	5·6	− 72	− 13	− 20	− 16	19
	58	43·9	55·3	26	65	6·7	− 38	36	40	38	87
	59	45·4	58·5	23	59	7	− 3	54	45	50	106
	60	46·4	59·6	21	53	5	+ 35	88	65	76	104
	61	42·7	53·6	25	68	5	− 24	35	32	34	62
	62	45·6	55·6	23	64	4·5	− 7	46	38	42	63
	63	43·6	53·6	22	62	5	− 14	48	53	50	78
	64	43·2	53·3	24	63	6	0	45	35	40	82
	65	39·9	50·6	21	53	5·6	− 13	40	34	37	72
	66	44·1	54·5	24	62	5·6	− 33	20	13	16	51
	67	44·8	54·7	22	58	5·6	− 14	35	23	29	64



22 *Photomicrograph of forging no.3, C steel* × 100



24 *As Fig.22, forging no.17, Ni steel* × 100

core and cast analysis, and by ± 0·04% within the core itself. It will be seen from Table XV that all the turbine wheels, and 15 of the rotor shafts were made of Cr–Mo steel with the Cr content ranging from 2·31 to 3·96%, but falling mainly in the range 3·0–3·5%. Throughout this work, particular attention has been paid to the forgings of this composition, but forgings of other compositions have been included because they are commonly used.

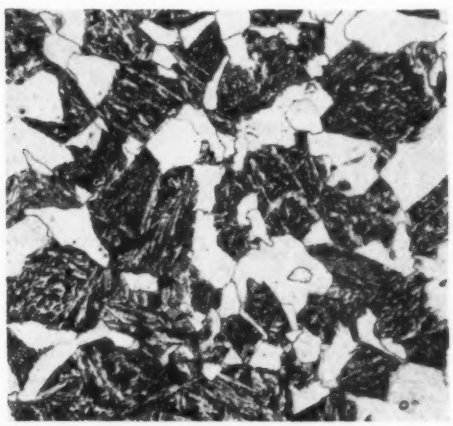
The dimensions of the rotor shafts range from 31 in. to 57 in. body dia. by up to 36 ft in overall length; the turbine wheels, which are made as up-ended discs with a central hole, are 48–62 in. outside dia. and 5¼–16¾ in. thick at the hub.

After forging, the rotor shafts are annealed, re-austenitized, and cooled in air (or air and furnace) until completely transformed, and then tempered. The turbine wheels are annealed, rough machined all over (including the bore), hardened by air cooling or oil quenching, and tempered. To keep residual stresses low, all the forgings are slowly cooled from the tempering temperature at a rate dependent on the size of the forging. The 3%Cr–Mo forgings were austenitized at 900–950° C and tempered at 620–690° C.

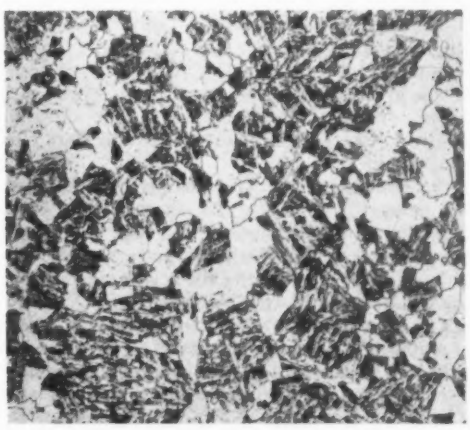
Test procedure for forgings

Test material for this investigation was obtained after the forgings had been tempered. An axial core of 1–2 in. dia. was trepanned from each rotor shaft, and the portion corresponding to the mid-length of the body was used for test; an annulus of 2 in. radial thickness was trepanned from the bore of each turbine wheel. The direction of testing was longitudinal for the rotor shafts, and tangential for the turbine wheels. Some preliminary tests on turbine-wheel material had shown that the transition temperature in the axial direction was not significantly different from that in the tangential direction, although in the former case the energy required to fracture the test piece was lower for a given proportion of cleavage in the fracture.

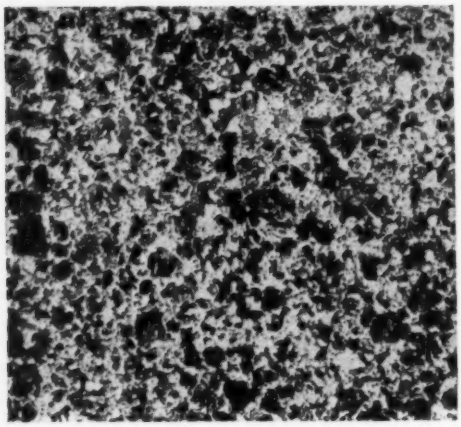
Charpy V-notch specimens were broken at various temperatures, and the transition temperatures were determined as in Part I. The results are given in Table XVI. In addition, the temperature for 15 ft-lb energy absorption has been included in the data as a matter of interest, since this criterion has sometimes been used in transition temperature work, particularly in the USA. Unless otherwise stated, however, all



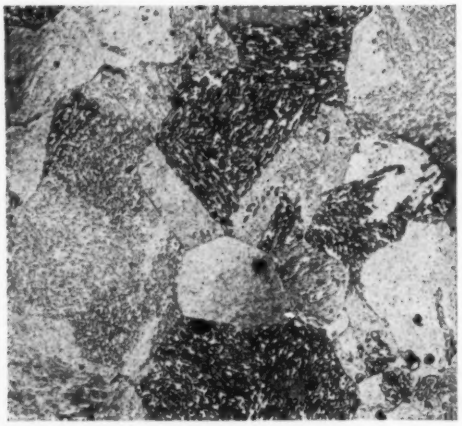
23 *As Fig.22, forging no.12, C–Mo steel* × 100



25 *As Fig.22, forging no.23, Ni–Cr–Mo steel* × 100



26 *As Fig.22, forging no.27,* Ni–V *steel* × 100



27 *As Fig.22, forging no.39,* 3%Cr–Mo *steel* × 100

references to transition temperature in this investigation are to the average of the mean energy and 50% cleavage transition temperatures.

Microstructure of forgings

Microscopical examination was carried out on one of the aforementioned Charpy test pieces from each forging. The primary object was to determine the grain size of the parent austenite, but attention was also paid to the nature of the transformation product. The Cr–Mo steels consisted almost entirely of tempered bainite (occasionally a very small amount of pearlite was observed in the test material from the rotor shafts). All the other steels contained considerable amounts of free ferrite, accompanied by pearlite (in the 1%Ni, Ni–V, and C steels) or bainite (in the C–Mo and Ni–Cr–Mo steels). Typical photomicrographs are shown in Figs. 22–27.

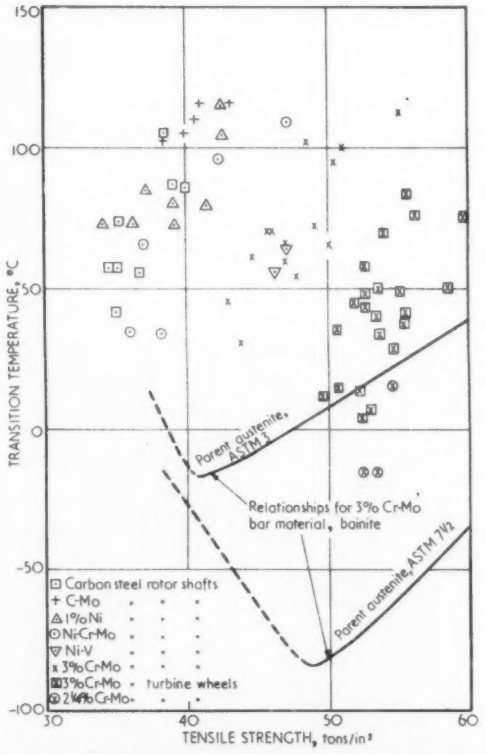
In spite of the proportion of free ferrite present in some of the rotor shafts, the grain size recorded is that of the parent austenite, and was usually somewhat coarser than that of the free ferrite by up to two ASTM nos.

Consideration of test results

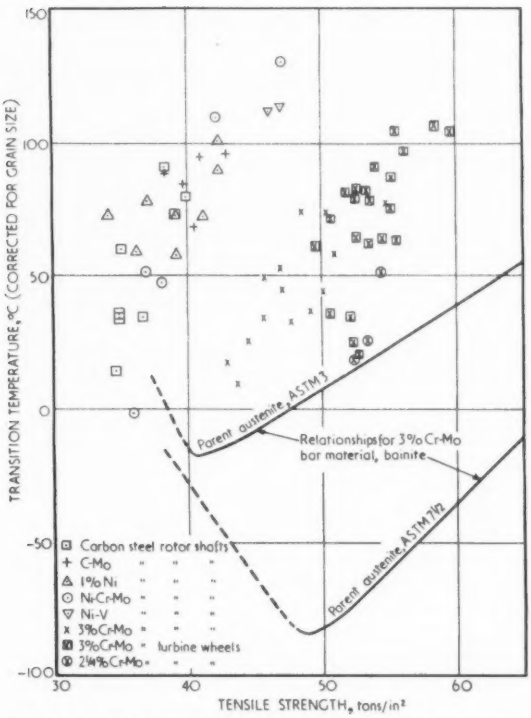
An examination of the results recorded in Table XVI shows that the transition temperatures of the forgings cover a wide range. In an attempt to explain this, and to explain why 3%Cr–Mo forgings, for example, give higher values than those which can be obtained on small-diameter rolled bar of similar composition, the principles established in Part I have been applied.

If the transition temperatures are plotted against tensile strength, as in Fig. 28, there is at first sight little evidence of correlation, but the points lie in three groups: turbine wheels towards the lower right-hand side, most of the rotor shafts towards the upper left-hand side, and 3%Cr–Mo and Ni–V rotor shafts in an intermediate position. The two diagonal lines across the bottom right-hand corner of Fig. 28 and the two subsequent graphs represent the relationships established in Part I between transition temperature and tensile strength of 3%Cr–Mo rolled bar heat-treated to give tempered bainite for parent austenite grain sizes of ASTM3 and 7·5.

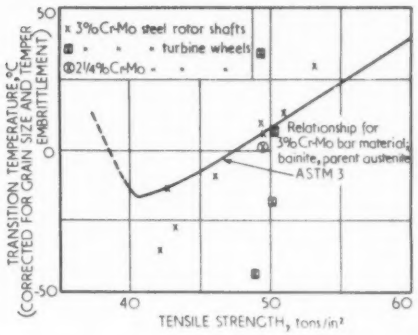
In spite of their higher tensile strength, the turbine wheels have transition temperatures which are equal to or lower than those of the rotor shafts. A probable explanation of this is the smaller austenite grain size of the turbine-wheel forgings. The effect of varying austenite grain size has therefore been eliminated by correcting the transition temperatures at the rate of 14° C per ASTM no. to a common grain size of ASTM3 which is a convenient value intermediate between those of the rotor shafts and turbine wheels,



28 *Relationship between transition temperature and tensile strength in forging as works treated*


TRANSITION TEMPERATURE, °C (CORRECTED FOR GRAIN SIZE)
TENSILE STRENGTH, tons/in²
Parent austenite, ASTM 3
Relationships for 3% Cr-Mo bar material, bainite
Parent austenite, ASTM 7½
Carbon steel rotor shafts
C-Mo " " "
1% Ni " " "
Ni-Cr-Mo " " "
Ni-V " " "
3% Cr-Mo " " "
3% Cr-Mo " turbine wheels
2¼% Cr-Mo " " "

29 *As Fig.28, transition temperature corrected to a parent austenite grain size of ASTM3*


TRANSITION TEMPERATURE, °C (CORRECTED FOR GRAIN SIZE AND TEMPER EMBRITTLEMENT)
TENSILE STRENGTH, tons/in²
3% Cr-Mo steel rotor shafts
" " " turbine wheels
2¼% Cr-Mo " " "
Relationship for 3% Cr-Mo bar material, bainite, parent austenite ASTM 3

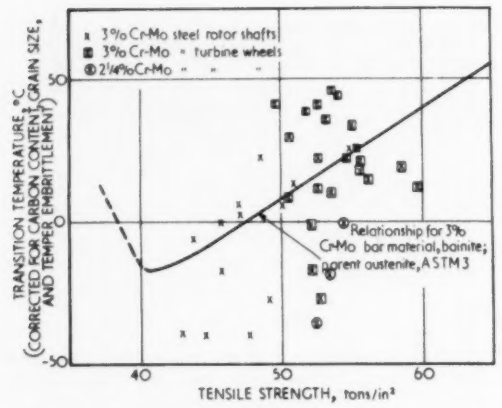
30 *As Fig.28, transition temperature corrected to a parent austenite size of ASTM3, in the non-temper embrittled condition (1 h at 650°C, WQ)*

and for which a transition temperature tensile strength relationship has been derived in bar material. The corrected results have been re-plotted in Fig. 29, and are now seen to fall into two main groups, with all the Cr–Mo steels towards the lower right-hand side and all the others (including Ni–V) towards the upper left-hand side. This segregation into two groups can be explained by consideration of the microstructures. The Cr–Mo steels consist almost exclusively of tempered bainite, while the microstructures of the others consist either of pearlite and free ferrite, or bainite with a considerable amount of free ferrite. Although no systematic examination was made in Part I of the effect of free ferrite on transition temperature, it is to be expected that there will be an increase in average ferrite grain size and, therefore, of transition temperature as a result of free ferrite being present. It is of interest that the forgings represented by the top left-hand group in Fig. 29 tend to lie in one band in spite of their varied composition, suggesting that for this group, chemical composition has less influence on

TABLE XVII Mechanical properties of forging material after a re-treatment of 1 h at 650°C, WQ

Treatment: as received			As received + 1 h/650°C WQ								
Forging no.	M.S., tons in²	Average transition temp., °C	YP tons / in²	MS tons / in²	Elong., %	Red. in area, %	Parent austenite grain size ASTM no.	Transition temperature, °C (a) Mean energy	(b) 50% Cleavage	(c) Average of (a) and (b)	(d) (c) Corrected to ASTM3
Rotor shafts											
29	49·2	72	28·8	49·4	23	60	0·1	47	44	44	9
31	43·8	31	33·4	42·2	29	69	1·2	−15	−14	−15	−36
32	45·8	70	33·3	42·8	28	71	1·2	6	7	7	−14
34	43·0	46	39·0	51·0*	23	60	1	...	41	41	13
35	44·6	61	33·4	43·4	29·5	69·5	0·1	7	7	7	−28
36	51·0	100	41·8	53·2	22·5	61·5	0	80	64	72	30
38	47·1	66	38·1	46·1	24	67·5	1–2	10	13	12	−9
39	50·4	95	40·4	49·7	21	61·5	1·2	...	27	27	6
Turbine wheels											
45	52·4	4	39·8	50·2	26	73	4·5	−38	−40	−39	−18
46	52·8	7	39·0	49·0	27·5	74	4	−61	−55	−58	−44
47	50·6	15	39·6	50·4	22·5	66·5	4·5	−16	−14	−14	7
48	49·6	12	39·2	49·4	25	66·5	6·7	−14	−16	−15	34
56	53·5	−16	38·4	49·6	26	66·5	6	−45	−36	−41	1

* Value higher than as received only owing to local higher carbon content



31 *As Fig.28, transition temperature corrected to a carbon content of 0·26%C and a parent austenite grain size of ASTM3, in the non-temper embrittled condition (1 h at 650°C, WQ)*

transition temperature than tensile strength and grain size. It is also now clear that Ni–V steel, which at first appeared to be different from the others in this group, was different only because of its very fine grain size.

Correction of the transition temperatures of the Cr–Mo steels for grain size has brought the rotor shafts and turbine wheels into one group but there is still a considerable amount of scatter. Statistical analysis of the data gives a regression line for this group with a slope of 4·5° C/ton/in², or, disregarding the grain size correction and analysing the original data for all the Cr–Mo steel forgings, the following multiple regression equation is obtained:

$$\text{Transition temperature in } ^\circ\text{C} = 4 \cdot 4\,\text{MS} - 13 \cdot 3\,\text{GS} - 131.$$

i.e. the dependence of transition temperature on maximum stress (MS) and parent austenite grain size (GS) is very similar to the values of 3·0–5·0 and 14·0, respectively, which were established in Part I for 3%Cr–Mo rolled bar. Transition temperatures calculated by means of this equation fall within ± 30° C of the experimental values, with only four exceptions, all turbine wheels.

All the results in Fig. 29 still lie somewhat above the line representing 3%Cr–Mo rolled bar of the same parent austenite grain size, but it should be remembered that all the forgings were slowly cooled after tempering and may therefore be affected by temper brittleness. To eliminate any such effect, test material, where available, was re-tempered in the laboratory for 1 h at 650° C and water quenched; the transition temperature and tensile strength were measured on this re-treated material and the results are given in Table XVII. These newly determined transition temperatures, corrected to ASTM3, are plotted against tensile strength in Fig. 30, where it will be seen that they now lie near to the line representing 3%Cr–Mo rolled bar. The few results available on rotor shaft material lie quite close to the line, but the turbine-wheel results still show a considerable amount of scatter.

The reason for this scatter is not at present clear. It cannot be significantly accounted for by differences in carbon content between the several casts. It is also not at present clear why the embrittling effect caused by slow cooling varies from one forging to another. Attempts to correlate the amount of embrittlement with the phosphorus and tin contents of the various forgings have so far proved unsuccessful.

As further test material was not available for the remaining 3%Cr–Mo forgings, (i.e. other than those in Table XVII), the average decrease in transition temperature as a result of the re-treatment at 650° C was calculated from Table XVII, allowing for any difference in MS resulting from 650° C treatment. This average decrease, 42° C, was then applied as a correction factor to the transition temperature (already corrected) to a parent austenite grain size of ASTM3 of the remaining 3%Cr–Mo forgings. In addition, the transition temperature has been corrected for a carbon content of 0·26%, which was the value for the bar material, and to the maximum stress value obtained before treatment at 650° C. The final results together with those from Fig. 30 (now also corrected for carbon content and maximum stress value) are shown in Fig. 31.

All the points now lie about the line for bar material, about half the points lying within a band of ± 10° and the majority within about ± 30°. The scatter is in part due to a possible inaccuracy of about ± 20° in the assumed correction factor for temper embrittlement.

Some preliminary work which has been done on forgings other than of 3%Cr–Mo steel suggests that some of these steels are affected to only a small extent, if any, by temper brittleness after slow cooling from the tempering temperature.

It was pointed out in Part I that the transition temperature of 3%Cr–Mo steel was not significantly affected by the rate of cooling from the austenitizing temperature, provided that the transformation product was bainite. The results obtained on the 3%Cr–Mo forgings confirm this, since, when allowance is made for the differences in grain size and tensile strength, transition temperatures of rotor shafts, 37–57 in. dia. air cooled from the austenitizing temperature, are similar to those obtained on turbine wheels less than 10 in. thick and oil hardened.

DISCUSSION

The most important point that emerges from the present work is that the transition temperature of material from a large forging can be accounted for and even predicted by means of four principal parameters, namely (*a*) parent austenite grain size, (*b*) transformation product, (*c*) tensile strength, and (*d*) extent of temper embrittlement. For 3%Cr–Mo steel, carbon content is a fifth parameter.

The transition temperature is lowered by about 14° C for a parent austenite grain refinement equivalent to one ASTM no., and by 3·2° C for each ton/in² reduction in tensile strength. Little advantage can be taken of the latter relationship because the forging must have sufficient tensile strength to withstand service stresses. A fine austenite grain size is also not easily obtained, since the slow heating and prolonged soaking which are necessary with such large forgings as rotor shafts lead to grain growth; it may be possible, however, to inhibit grain growth by alloy additions such as vanadium. On the other hand, a fine austenite grain size reduces hardenability and by

increasing the transformation temperature may tend to increase the transition temperature.

It does not appear to be practicable at the present time to transform very large forgings to martensite. A 3%Cr–Mo steel can be transformed to bainite, however, and for a given tensile strength, steel of this composition was found to give lower transition temperatures than steels of other compositions which contained pearlite or appreciable amounts of free ferrite in their structures. Although forgings of 3% Cr–Mo steel seemed to be the most susceptible to temper embrittlement, they still had lower transition temperatures than the majority of the other compositions studied.

Since rapid cooling of large forgings from the tempering temperature would introduce very high residual stresses, this appears to be an impracticable method of eliminating temper brittleness. Some reduction in the degree of embrittlement may be achieved, however, by modifying the chemical composition of the steel. Phosphorus has been shown by others to increase temper brittleness, but no correlation was found in the present work between the degree of embrittlement and phosphorus content, possibly because the variation in composition was too small in the forgings tested in this investigation.

At the present time the most promising method of obtaining a low transition temperature in large forgings appears to be by suitably modifying the composition so as to obtain (*a*) a fine parent austenite grain size, (*b*) sufficient hardenability to suppress transformation in the pearlite region, and (*c*) as little temper brittleness as possible. A considerable amount of experimental work will be needed, however, before transition temperatures below room temperature can be consistently achieved.

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STAL *in English*

Number 6 (June 1959) of the cover-to-cover translation of the Russian journal *Stal'* has been published, and subsequent issues should appear at about monthly intervals. Full details of subscriptions to *Stal in English* are available from the Secretary of The Iron and Steel Institute.

Gravimetric determination of lead in iron and steel (lead content > 0·05%)

BISRA Methods of Analysis Committee

SYNOPSIS

A method based on the precipitation of lead as sulphide and conversion to lead molybdate has been examined on a range of steels containing more than 0·05% lead. The method has been shown to be free from interference from copper, chromium, molybdenum, nickel, up to 0·25% tin, and up to 2% tungsten. A reproducibility of ± 0·01% at 0·2% lead content is claimed. 1758

INTRODUCTION

THE METHODS OF ANALYSIS COMMITTEE was asked in 1952 to reconsider the British Standard method for lead in steels, BS 1121: Part 1C: 1943, which had been specially developed for leaded steels containing from 0·2% to 0·3% of lead. It was known that the method was unsuitable for materials other than carbon steels, and that the accuracy was doubtful at levels below 0·1%.

The Pig Iron, Carbon, and Low-Alloy Steels Analysis Sub-Committee* therefore undertook to develop a revised method for lead in steel which would be applicable to a wider range of materials and to all concentrations of lead.

EXPERIMENTAL INVESTIGATION

BS 1121: Part 1C was based on the precipitation of lead sulphate and conversion to lead molybdate, and there was evidence that the separation as sulphate was liable to cause low recoveries of lead. It was suggested that the introduction of a hydrogen sulphide precipitation from a weakly acid solution would overcome this difficulty and enable the method to be extended to lower lead contents.

A method using a preliminary sulphide separation followed by precipitation as sulphate and finally weighing as lead molybdate had already been published[1] and this was given a preliminary trial on a manganese–molybdenum steel, a high-sulphur steel, and a free-cutting stainless steel (*see* Table I).

The preliminary results obtained are reported in Table II and whilst these showed fair agreement it was found that difficulty was experienced in completing the solution of lead sulphide from the filter paper by washing with dilute nitric acid. It was also confirmed that the intermediate separation of lead sulphate introduced an error due to the slight solubility of the sulphate. Further preliminary work led to the suggestion that the conversion to sulphate might be omitted altogether.

The method was therefore re-drafted so that after

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*The constitution of the Sub-Committee at 31 March 1958 was as follows: Mr S. W. Craven, ICI Ltd (Chairman); Mr W. E. Clarke, BCIRA; Mr P. E. Clary, Ford Motor Co. Ltd; Mr L. J. Clements, Round Oak Steel Works Ltd; Mr C. B. Clyde, Lanarkshire Steel Co. Ltd; Mr L. E. Gardner, Edgar Allen and Co. Ltd; Mr D. P. Hunter, Steel Company of Wales Ltd; Mr R. F. Jones, Steel Company of Wales Ltd; Mr P. D. Ridsdale, Bureau of Analysed Samples Ltd; Mr A. Walker, John Lysaght's Scunthorpe Works Ltd; Mr H. J. Turner, Steel Peech and Tozer; Mr W. Ivor Williams, Guest Keen Iron and Steel Co. Ltd.

Thanks are also due to Mr F. V. Gleeson, Lancashire Steel Manufacturing Co. Ltd; Mr A. P. Lunt, Park Gate Iron and Steel Co. Ltd; Mr A. W. Reed, Consett Iron Co. Ltd; and Mr C. W. Short, John Lysaght's Scunthorpe Works Ltd; who were members of the Sub-Committee during the investigation.

TABLE I Approximate percentage composition of steels used in a preliminary trial

Sample no.	C	Mn	Si	S	Ni	Cr	Mo	Cu
MGS/195	0·28	0·96	0·16	0·03	...	...	0·05	...
MGS/196	0·13	1·18	...	0·23	...	...	...	...
MGS/197	0·07	0·61	0·30	...	12·3	14·1	...	0·14

TABLE II Preliminary results of analyses

Analyst	Lead, % MGS/195	MGS/196	MGS/197
1	0·17	0·15	0·25
2	0·168	0·144	0·251
3	0·16	0·135	0·24
4	0·134	0·122	0·254
5	0·178	0·145	0·256
6	0·171	0·134	0·268
7*	0·17	0·145	0·25
8*	0·185	0·15	0·255

*Omitting conversion to sulphate

TABLE III Results of analysis using re-drafted method

Analyst	Lead recoveries from lead-free steel, % (0·05%Pb added)	Analyst	Lead recoveries from lead-free steel, % (0·05%Pb added)
1	0·051	6	0·051
2	0·050	7	0·049
3	0·049	8	0·051
4	0·054	9	0·048
5	0·049		

TABLE IV The effect of copper and nickel additions on the determination of lead

Test no.	Copper added, mg	Nickel added, mg	Copper found corrected for reagents, mg 1st precipitation	Copper found corrected for reagents, mg 2nd precipitation	Nickel found corrected for reagents, mg 1st precipitation	Nickel found corrected for reagents, mg 2nd precipitation
1	1		0·006			
2	2		0·008			
3	3		0·009			
4	4		0·010			
5	20		0·020			
6	20			trace		
7		20			0·005	No 2nd precipitation as contamination was negligible after first precipitation
8		20			0·008	

precipitation of the lead sulphide from a dilute hydrochloric acid solution, followed by filtration, the lead was converted directly to molybdate without the intermediate sulphate separation.

With synthetic solutions this procedure gave satisfactory recoveries of lead at the 0·05% level (*see* Table III). After establishing that this method justified further investigation, the effect of possible interference from copper, nickel, molybdenum, tin, and tungsten was examined.

Lead molybdate was precipitated from solutions containing 10 mg of lead with separate additions of between 1 and 20 mg of copper, and 20 mg of nickel. After standing for 4 h, the precipitates were filtered, washed, ignited, and weighed, and the copper and nickel contents determined. Lead additions from 0·005% to 0·05% were also made to a lead-free steel, to which copper up to 0·2%, and 0·1% molybdenum were added. From the results of these tests, shown in Tables IV and V, it was considered that the effect of copper and nickel was not significant although reprecipitation of the lead molybdate did reduce the small contamination observed.

TABLE V Analysis of a lead-free sample in the presence of 0·2% copper and 0·1% molybdenum

Analyst	Lead addition, %	Lead recovered, % 1st precipitation	Lead recovered, % 2nd precipitation
1	0·005		0·005
	0·010		0·009
	0·020		0·018
2	0·010	0·014	0·011
	0·020	0·022	0·019
	0·030	0·032	0·028
3	0·0063		0·0059

TABLE VI Typical results obtained with tin and tungsten added

Test no.	Tin added, %	Tungsten added, %	Lead, % 1st precipitation	Lead, % 2nd precipitation
1			0·175	0·172
2			0·171	0·169
3	0·05		0·176	0·170
4	0·10		0·179	0·168
5	0·25		0·185	0·162
6	0·05	2·0	0·159	0·155
7	0·10	2·0	0·157	0·158
8	0·25	2·0	0·162	0·147

Similarly no evidence was obtained that molybdenum interfered in the sulphide–molybdate procedure.

Difficulties were, however, experienced with both tin and tungsten. Typical results derived from experiments in which sodium tungstate and stannous chloride solutions were added to 10-g portions of sample MGS/165, equivalent to 2·0% tungsten and 0·05%, 0·10%, and 0·25% tin are shown in Table VI.

It will be seen that tin causes a small positive error in the first precipitation of lead molybdate but in the presence of tungsten and tin results for lead tend to be low.

It was noted that during the evaporation of the nitric acid solution of the mixed sulphides to 10 ml as specified, appreciable amounts of metastannic acid separated from solution. In order to retain all the tin in solution until after the addition of tartaric acid, 5 ml of hydrochloric acid was added and further experiments showed that by means of this modification interference from up to 0·25% of tin was eliminated (*see* Table VII). The interference of tungsten up to 2·0% was found to be satisfactorily overcome by adding hydrofluoric acid in the solution mixture (*see* Table VII) care being taken to use lead-free glass to avoid possible contamination arising from attack on the glass by hydrofluoric acid.

During the early experimental work it had been observed that the ignited lead molybdate precipitates were generally faintly discoloured and that the discolouration persisted even after a double precipitation of lead molybdate. The discolouration was undoubtedly due to traces of iron and an attempt was made to determine its effect on the results for lead.

Lead molybdate was precipitated from solutions each containing 10 mg of lead, and between 0·4 mg and 10 mg of iron, when the colour of the precipitates after ignition varied from buff to light brown. These precipitates were examined for iron and the highest iron content including the blank in the reagents was

TABLE VII Results obtained with tin and tungsten added and using hydrofluoric acid

Test no.	Tin added, %	Tungsten added, %	Lead, % 1st precipitation	Lead, % 2nd precipitation
1		2·0	0·166	0·164
2		2·0	0·167	0·164
3		2·0	0·173	0·169
4		2·0	0·169	0·165
5		2·0	0·166	0·163
6	0·25		0·174	0·168
7	0·25		0·174	0·168

TABLE VIII Lead recoveries from synthetic solutions

Analyst	Lead recoveries from lead-free steel, % (0·005%Pb added)	Analyst	Lead recoveries from lead-free steel, % (0·005%Pb added)
1	0·0058	5	0·0049
2	0·0050	6	0·005
3	0·0045	7	0·005
4	0·0064	9	0·0045

120 μg which is equivalent to 0·0009%Pb in a 10-g sample.

From these results it is evident that it is sometimes possible for iron, in amounts so small as to have little effect on the accuracy of the lead determination, to produce a definite discolouration of the lead molybdate precipitates. It is also clear that the degree of such discolouration does not always provide a reliable indication of the quantity of iron present. It was, however, considered desirable to include in the final procedure a clause recommending that a second precipitation should be made whenever the colour of the lead molybdate first obtained suggested that it might be contaminated by a significant amount of iron.

This left the determination of trace amounts of lead in steel still in abeyance, so a further study of lead recoveries from synthetic solutions was undertaken as shown in Table VIII. These were thought to be satisfactory and the Bureau of Analysed Samples Ltd, spectrographic standards 11–17 were analysed, re-precipitating the lead molybdate to remove contamination of the precipitate, which might be expected to be more significant at the lower lead contents.

The results given in Table IX showed that the method was not sufficiently reproducible at these levels although one or two analysts were satisfied with the procedure. A separate investigation of a photometric procedure was started, based on the reaction of lead with dithizone[2,3,4] to provide for the determination of trace amounts of lead. This work is still in progress and will be reported in due course.

It was therefore decided that the gravimetric method for lead should be recommended for lead contents greater than 0·05% and it was re-drafted (*see* Appendix) to take account of elements known to interfere, for example, the hydrochloric acid addition was included in the method as many commercial steels contain tin. A series of typical lead-containing steels,

TABLE IX Results of analysis of trace amounts

Analyst	Lead, % SS11	SS12	SS13	SS14	SS15	SS16	SS17
1	0·003	0·004	0·003	0·010	0·007	0·008	0·007
2	0·003	0·003	0·003	0·002	0·005	0·002	0·006
	0·004	0·004	0·004	0·004	0·005	0·003	0·006
3	0·002	0·016	0·002	0·005	0·003	0·002	0·003
	0·002	0·016	0·002	0·005	0·003	0·002	0·003
4	0·004	...	0·002	0·011	0·008	0·007	0·008
	...	0·002	...	...	...	...	...
5	0·005	0·003	0·006	0·002	0·006	0·008	0·008
	0·004	0·002	0·004	0·003	0·006	0·006	0·006
6	...	...	...	...	0·007	0·008	0·015
	0·003	0·004	0·007	0·012	...	...	...
7	0·005	<0·002	<0·002	<0·002	0·004	<0·002	<0·002

for which the approximate compositions are given in Table X, were then analysed and the results of these tests are shown in Table XI. These results were considered acceptable and the method has been submitted to the British Standards Institution to supersede BS 1121: Part 1C: 1943.

CONCLUSION

A method based on the precipitation of lead as sulphide and conversion to lead molybdate is recommended for the determination of lead at levels greater than 0·05% in steel. This method has been shown to be free from interference from chromium, copper, molybdenum, nickel, up to 0·25% tin, and up to 2% tungsten.

A reproducibility of ±0·01% at 0·2% lead is claimed for the recommended method.

The method is not considered to be satisfactory for less than 0·05% lead and a photometric procedure is being investigated for these levels.

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4. Confidential communication from BISRA Physico-Chemical Methods of Analysis Sub-Committee.

TABLE X Approximate percentage composition of the samples

Sample no.	C	Si	S	P	Mn	Ni	Cr	Mo	V	As	Cu	Others	Type
MGS/163	0·415	0·13	0·02	0·05	0·73	0·04	0·02	<0·01	0·02	0·005	0·1	Co 0·02	Lead steel BCS 212
MGS/196A	0·07		0·322	0·070	1·00								Lead free-cutting steel
MGS/257A	0·10		0·314	0·078	1·50								Lead free-cutting steel
MGS/272	0·11		0·252	0·06	1·15	0·08	0·08				0·18	Sn 0·03	Lead free-cutting steel
MGS/274	0·29	0·224	0·04	0·04	1·04	0·10	0·06	0·01			0·16	Sn 0·01	Carbon steel
MGS/360	0·20				0·57	1·96	1·38	0·21					Lead steel with 1% chromium

APPENDIX

Introduction

Principle

Lead is precipitated as sulphide from dilute hydrochloric acid solution, filtered, dissolved in nitric acid, and converted to lead molybdate.

Range

Lead contents between 0·05% and 0·40%.

Reproducibility

±0·01% lead.

Application

The method is applicable to carbon and leaded steels which may contain copper, chromium, molybdenum, nickel, up to 0·25% tin, and up to 2% tungsten.

Apparatus

Grade 'A' graduated glassware shall be used. Pipettes complying with BS 700* and graduated flasks complying with BS 1792† are suitable.

Reagents required

All reagents shall be of the highest purity obtainable and distilled water‡ shall be used throughout. Solutions shall be freshly prepared and, where necessary, filtered.

Solutions

Hydrogen sulphide–hydrochloric acid wash solution Dilute 5 ml of hydrochloric acid (sp. gr. 1·16–1·18) to 1 l. and pass a rapid stream of washed hydrogen sulphide gas through the solution for not less than 10 min.

Nitric acid (40% *v/v*) Dilute 500 ml nitric acid (sp. gr. 1·42) to 1 l.

Tartaric acid (50% *w/v*) Dissolve 500 g of tartaric acid in water and dilute to 1 l.

Ammonia (50% *v/v*) Dilute 500 ml ammonia solution (sp. gr. 0·880) to 1 l.

Ammonium molybdate (5% *w/v*) Dissolve 50 g ammonium molybdate ($(NH_4)_6Mo_7O_{24}4H_2O$) in water, add ammonia solution (50% v/v), until just alkaline to litmus paper and dilute to 1 l.

Ammonium acetate solution (2% *w/v*) Dissolve 20 g ammonium acetate in water, make just acid to litmus paper with glacial acetic and dilute to 1 l.

Sampling

Recommended methods of obtaining a suitable sample for the analytical procedure outlined below are described in BS 1837: Part 1, 'Methods for the sampling of iron and steel'.

Procedure

Weigh 10 g of sample and transfer to a 650-ml conical beaker, add 70 ml of hydrochloric acid (sp. gr. 1·16–1·18) and 30 ml water. Warm gently to complete solution and evaporate almost to dryness (note 1). Add 200 ml of warm water, boil until a clear solution is obtained (note 2), and filter through a paper-pulp pad, washing well with hot water. Dilute the filtrate to about 400 ml.

* BS 700 'Graduated pipettes and one-mark pipettes'.

† BS 1792 'One-mark graduated flasks'.

‡ Water demineralized by ion exchange may be used.

TABLE XI Results of analysis of samples listed in Table X

Analyst	Lead, % MGS/ 163	MGS/ 196A	MGS/ 257A	MGS/ 272	MGS/ 274	MGS/ 360
1	$0·26_5$	$0·17_0$	0·070	$0·11_0$	$0·18_5$	
2	$0·28_0$	$0·17_5$	0·069	$0·11_0$	$0·18_0$	$0·17_5$
3		$0·17_5$	0·074	$0·11_5$	$0·18_5$	
4	$0·28_0$	$0·17_5$	0·080	$0·11_5$	$0·19_5$	$0·18_0$
5				$0·12_0$	$0·19_0$	$0·18_0$
6	$0·28_5$	$0·17_5$	0·078	$0·11_5$	$0·19_5$	
7	$0·28_0$	$0·17_5$	0·075			$0·17_0$
8		$0·16_5$	0·076	$0·11_5$	$0·19_0$	$0·17_0$
9	$0·27_0$	$0·17_5$	0·077			$0·17_5$
10	$0·28_0$	$0·18_5$	0·075			$0·17_5$
11	$0·28_0$	$0·18_0$	0·080			
12	$0·28_0$	$0·17_5$	0·081			$0·17_0$
13				$0·12_0$	$0·18_5$	
14				$0·11_0$	$0·18_0$	
15						$0·18_0$
Average	$0·28_0$	$0·17_5$	0·076	$0·11_5$	$0·18_5$	$0·17_5$

Cool to room temperature and pass a rapid stream of hydrogen sulphide through the solution for 20 min; filter through a paper-pulp pad and wash several times with the hydrogen sulphide wash solution.

Transfer the paper and precipitate to the original beaker, add 20 ml nitric acid (40%) and digest until the sulphides are dissolved. Dilute to 50 ml, filter through a Whatman no.40 paper into a 400-ml beaker and wash well with hot water. To the filtrate add 5 ml of hydrochloric acid (sp. gr. 1·16–1·18), then cool and add 5 ml tartaric acid solution (50%). Neutralize with ammonia solution (50%), add an excess of 5 ml and dilute to 150 ml with hot water.

Add 10 g ammonium chloride and boil. Add dropwise 10 ml ammonium molybdate solution (5%) and boil for 10 min (note 3). Allow to settle for 4 h, or overnight, filter on a paper-pulp pad, washing with hot ammonium acetate solution (2%) and ignite at a temperature not exceeding 650°C. Cool and weigh as lead molybdate (note 4).

Determine the blank value of the reagents concurrently with the test determination and make the appropriate correction.

Calculation

$$\text{Lead } \% = \frac{A \times 56·44}{\text{weight in g of sample}}$$

where A = weight in g of lead molybdate

Notes

1. The final stages of evaporation must be carefully regulated, preferably on a steam bath, to remove excess acid and avoid baking the residue.

2. If the solution does not clear on boiling add 1–2 ml hydrochloric acid (sp. gr 1·16–1·18). If the turbidity is due to the presence of tungsten in the sample, an addition of 5 ml hydrofluoric acid should be made.

3. Add a further 5 ml ammonia solution (50%) at this stage if the presence of an excess is not detectable by smell.

4. If the lead molybdate is discoloured, dissolve carefully in 5 ml nitric acid (40%), dilute, filter, and cool. Add 0·5 ml tartaric acid solution (50%) and repeat the precipitation as given in the procedure.

The creep and rupture properties of 2¼% chromium–1% molybdenum quality steel

A SUMMARY OF BRITISH DATA (1% CREEP STRAIN AND RUPTURE)

J. D. Murray, J. S. Blair, G. G. Foster, H. W. Kirkby, and J. Blackhurst

SYNOPSIS

A review has been made of the creep and rupture data available in this country on the 2¼Cr–1%Mo quality steel. This data is presented in the form of scatter bands and from it 100000-h values have been extrapolated. All the tests that are reported cover 32 heats of steel in the following form: 17 as bar, 4 as tube, and 11 as pipe. The actual test results were thus available up to the end of December 1957. 1743

INTRODUCTION

THE 2¼%CHROMIUM–1%MOLYBDENUM STEEL was originally used in the petroleum industry because of its ability to withstand certain corrosive environments encountered in such plants: also since it has excellent creep ductility it gives advance warning of failure which is particularly important in the petroleum industry because of fire hazards. In recent years it has been used in the steam power plant industry for tube and pipe applications and it is because of this latter application in particular that this document has been compiled.

The document contains what is believed to be all the relevant creep and rupture data available in this country on this steel. It has been collected together to facilitate the compilation of design stresses for this steel and has been accomplished by the collaboration of three steelmakers, one boilermaker, and one steelmaker/pipe fabricator. In addition recently published data* has also been included. The data relate to 32 heats of steel which cover the composition range

C	Mn	Si
0·082–0·17	0·38–0·69	0·13–0·38
Cr	**Mo**	
2·06–2·35	0·87–1·07	

Since this steel is used mainly for tubing and piping little attention has been paid, in testing, to the determination of low deformation strain data, (e.g. 0·1%, 0·2%), that which is available being of much too short a test duration to allow for reliable assessment. Consequently only the data related to rupture and 1% plastic strain are presented.

Paper MG/J/211/59 of the High-temperature Steels Committee of the Metallurgy (General) Division of the British Iron and Steel Research Association received 8 July, 1959. The views expressed are the authors' and are not necessarily endorsed by the Committee as a body.

The authors are with respectively: United Steels Companies Ltd, Stewarts and Lloyds Ltd, Babcock and Wilcox Co. Ltd, Brown-Firth Research Laboratories, and Brown Bayley Steels Ltd.

*A. I. SMITH *et al.*: *Proc. IME*, 1957, **171**, 918–942.

On the 1% plastic strain basis the tests extend to 14000 h at 1000°F (538°C), 17000 h at 1050°F (565°C), 12000 h at 1110°F (593°C), 7000 h at 1112°F (600°C), and 11500 h at 1150°F (621°C); on the basis of rupture the tests extended to 22000 h at 1000°F (538°C), 14000 h at 1050°F (565°C), 33000 h at 1100°F (593°C), 8000 h at 1112°F (600°C), 25000 h at 1150°F (621°C), and 7000 h at 1200°F (648°C).

There was no uniformity of test conditions since the temperatures and stresses were chosen by the individual companies for applications which they themselves had in mind.

PARTICULARS OF THE STEELS

The chemical analyses of the 32 casts examined and the different heat-treatments adopted are given in Table I, together with the key to their identification in the different graphs.

By virtue of its alloy content this steel is capable of appreciable air hardening. Consequently a number of heat-treatments have been used to give tensile strengths that are compatible with both fabrication and creep resistance requirements. The range of tensile properties obtained at temperatures up to 650°C is given in Table II.

It will be noted from Table I that the 32 casts were in the following form: 17 as bar, 4 as tube, and 11 as pipe.

PRESENTATION OF RESULTS

Most of the data is presented in the form of log stress *v.* log time to attain 1% plastic strain or log stress *v.* log time to rupture curves (Figs.1–4). Only at two

TABLE I 2¼%Cr–Mo quality steel chemical analyses

Cast no.	Material	Test laboratory	Steel supplier	Analyses, % Carbon	Manganese	Silicon	Chromium	Molybdenum	Heat-treatment	Symbol on graphs
37784	Bar (1in. dia.)	Brown	Brown	0·15	0·47	0·28	2·20	0·94	Normalize 900°C,	O
39429	,, ,,	Bayley	Bayley	0·11	...	...	2·11	0·97	tempered 725°C ½ h	
L.496	,, ,,	,,	,,	0·09	0·38	0·13	2·33	1·07	Anneal 840°C, tempered 630°C	
'A'	Tube	Babcock	US Co's	0·09	0·39	0·23	2·15	0·97	Anneal 930°C	●
H.7484	Bar (¾ in. dia.)	and Wilcox		0·13	0·44	0·18	2·25	1·07	Normalize 898°C, tempered 734°C ½ h	+
07180	Bar (1⅛ in. dia.)	Brown-Firth	Brown-Firth	0·11	0·47	0·28	2·25	0·99	Anneal 930°C	×
									Anneal 930°C, tempered 700°C 3 h	□
H.1277	Pipe (10⅛ in. od × 6 7/16 in id)	NPL	US Co's	0·14	0·43	0·23	2·21	1·01	Anneal 930°C	■
S.1770	Tube (2½ in. od × 1⅛ in. id)	,,		0·15	0·42	0·18	2·28	1·01	Anneal 920°C	
9004	Pipe (12¾ in. od × 8½ in. id)	Stewarts	Stewarts	0·17	0·39	0·24	2·12	0·92	Control anneal 960°C	△
4525	,, (10¾ in. od × 8 in. id)	and Lloyds	and Lloyds	0·15	0·50	0·18	2·12	0·90	cooled at 400°C/h,	
2880	,, (16 in. od × 14¾ in. id)	,,	US Co's	0·082	0·50	0·23	2·14	0·98	tempered 690°C	
2890	,, ,,	,,	,,	0·082	0·39	0·16	2·11	0·95	Anneal 930°C	▲
3049	,, ,,	,,	,,	0·085	0·44	0·25	2·14	0·97		
3049	,, ,,	,,	,,	0·14	0·41	0·26	2·15	0·94	950°C cooled to 720°C	◇
3051	,, ,,	,,	,,	0·11	0·69	0·17	2·24	0·98	in 2½ h held for 1½ h,	
3100	,, ,,	,,	,,	0·11	0·50	0·30	2·23	1·01	cooled to 500°C in 1 h	
3101	,, ,,	,,	,,	0·102	0·47	0·30	2·33	1·03		
3103	,, ,,	,,	,,	0·11	0·42	0·32	2·19	0·97		
H.7484	Bar (¾ in. dia.)	US Co's	US Co's	See above						
H.1277	Pipe (10⅛ in. od × 6 7/16 in. id)	,,	,,	See above					Anneal 930°C	◆
'B'	Tube (2 in. od × 1½ in. id)	,,	,,	0·12	0·57	0·25	2·24	0·88		
'C'	,, (2½ in. od × 1⅝ in. id)	,,	,,	0·12	0·54	0·25	2·28	0·90		
A.178	Bar (1⅛ in. dia.)	,,	,,	0·13	0·53	0·23	2·21	0·87	Normalize 898°C,	▽
S.6262	,,	,,	,,	0·10	0·45	0·25	2·27	0·98	tempered 734°C ½ h	
S.6230	,,	,,	,,	0·11	0·44	0·28	2·13	0·96		
S.5382	,,	,,	,,	0·12	0·49	0·16	2·35	0·95		
S.5271	,,	,,	,,	0·12	0·51	0·21	2·23	0·96		
S.6261	,,	,,	,,	0·13	0·44	0·38	2·32	0·97		
S.6258	,,	,,	,,	0·17	0·46	0·29	2·24	0·90		
H.5074	,,	,,	,,	0·11	0·45	0·24	2·20	0·91		
H.4869	,,	,,	,,	0·12	0·42	0·24	2·26	0·96		
H.4351	,,	,,	,,	0·13	0·40	0·26	2·06	0·93		
H.4409	,,	,,	,,	0·13	0·45	0·18	2·19	0·96		
H.4406	,,	,,	,,	0·14	0·46	0·20	2·22	0·96		

The symbols relate only to heat-treatment conditions not to the different casts.
Where tube and pipe materials were tested, with the exception of Stewarts and Lloyds tests which were all on pipe, the symbols have suffixes 'T' and 'P'.

TABLE II 2¼%Cr–Mo quality steel tensile properties

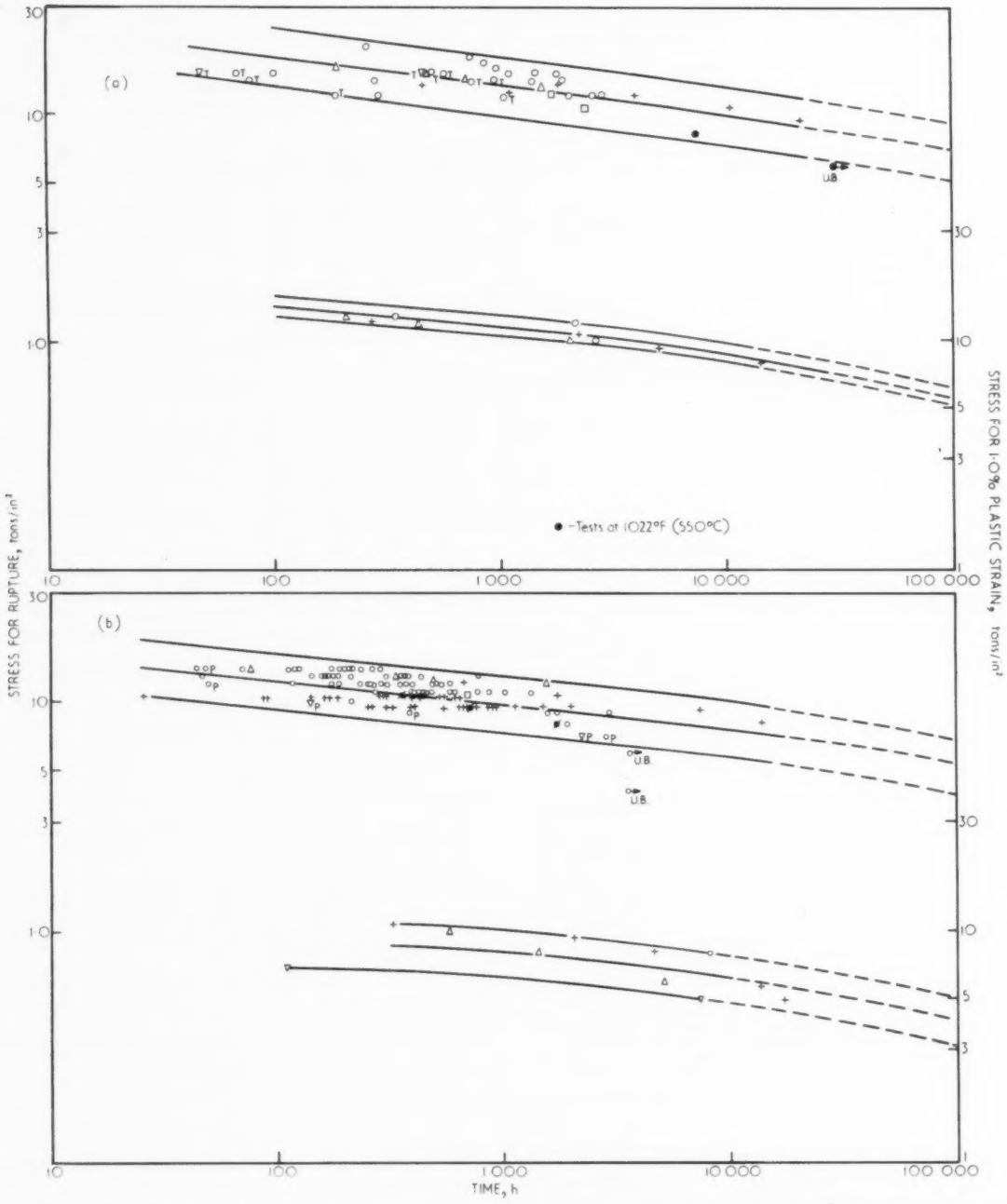
Heat-treatment: annealed 930°C (NPL and US Co's data)

Test temperature, °C	20	400	500	538	550	580	600	610	621	650
°F	68	752	932	1000	1022	1076	1112	1130	1150	1202
Tensile strength, tons/in²	32·6–34·4	33·2	28·7–29·9	25·0	25·2–25·8	21·9	21·2	18·3	19·1	15·3
Proof stress, tons/in² 0·1%	15·3–17·0	9·6	11·7–12·4	11·4	11·6–11·9	10·5	10·6	9·9	7·6	8·4
0·2%	15·9	...	...	12·4	...	11·5	...	10·7	8·1	...
Elongation on $4\sqrt{A}$, %	31·0–40·0	24·0	26·0–32·0	36·0	38·0–40·0	50·0	46·0	63·0	87·0	60·0
Reduction in area, %	53·0–61·0	58·0	58·0–63·0	75·9	67·0–68·0	79·5	75·0	85·0	90·2	84·0

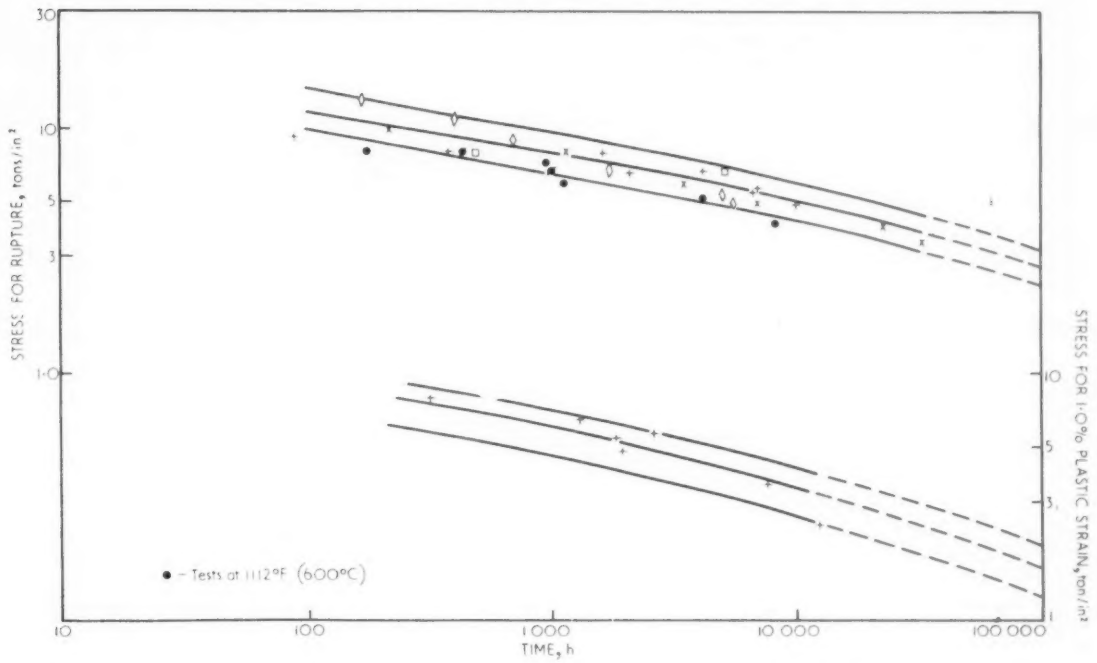
Heat-treatment: control annealed 960°C (cooled at 400°C/h tempered 690°C (Stewarts and Lloyds data)					Heat-treatment: normalized 898°C and tempered 734°C ½ h (US Co's data)			
Test temperature, °C	20	538	565	593	20	530	580	610
°F	68	1000	1050	1100	68	1000	1076	1130
Tensile strength, tons/in²	30·6–40·3	27·2	22·6	21·7	1·4	31·1	25·7	22·1
Proof stress, tons/in² 0·1%	...	...	...	...	36·0	24·3	16·5	14·6
0·2%	25·6	18·6	16·1	15·2	36·0	25·9	18·3	16·8
Elongation on $4\sqrt{A}$, %	30·0–40·3	32·2	35·7	37·4	30·0	32·0	42·0	54·0
Reduction in area, %	69·0–76·0	...			75·5	79·3	84·6	88·9

stress levels (5 and 7 tons/in²) was it possible to present test data in temperature *v.* log time to rupture diagrams (Figs.5 and 6).

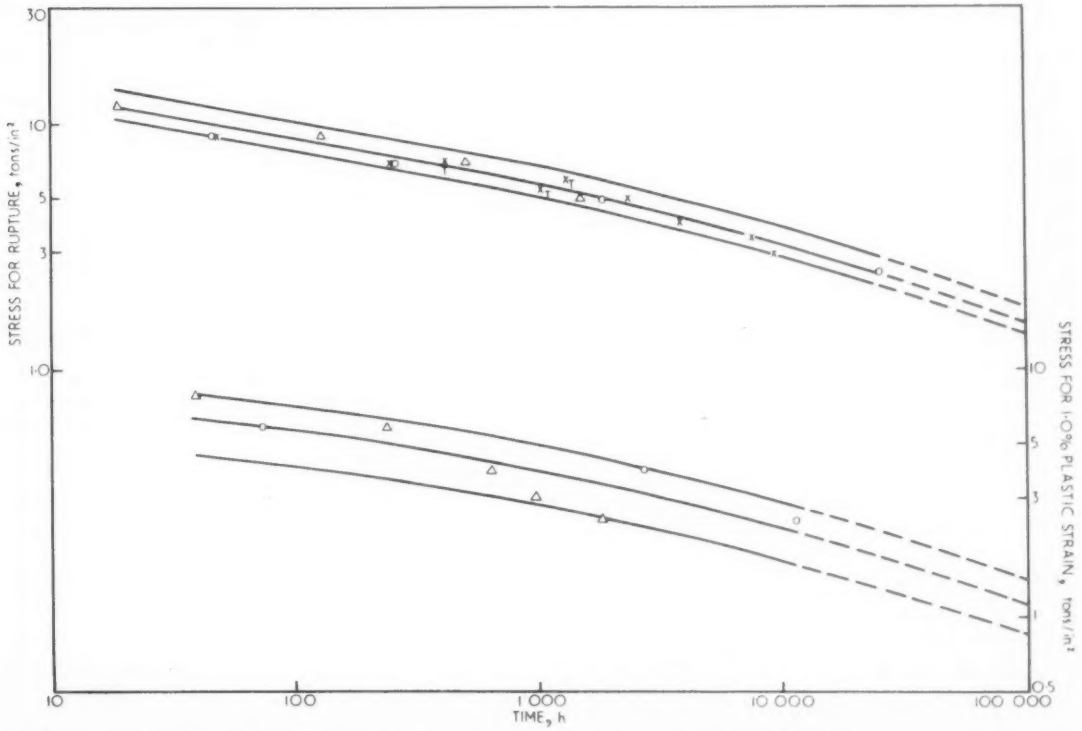
An indication of the good creep ductility of this steel is given in Figs.7–9, where the elongation at fracture has been plotted against the time to fracture. The large amount of variation in the elongation values is not only due to small variations in composition, manufacturing history, and heat-treatments, but also to the fact that the tests were made on geometrically dissimilar specimens. The results do indicate, in respect of creep ductility, that this steel conforms to conventional behaviour in that the ductility falls to some minimum value with increasing testing time and the minimum value attained decreases with a decrease in the test temperature.



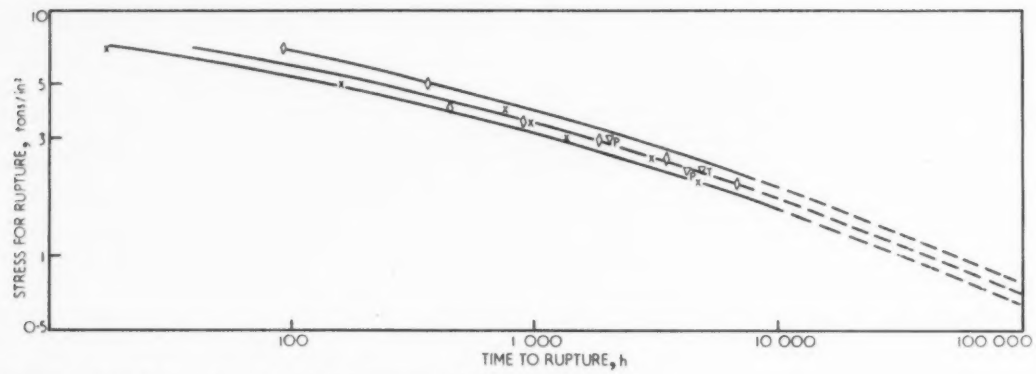
1 *Stress* v. *time to give 1·0% plastic strain and rupture at constant temperature* (a) *1000°F(538°C), and* (b) *1050°F (565°C)*



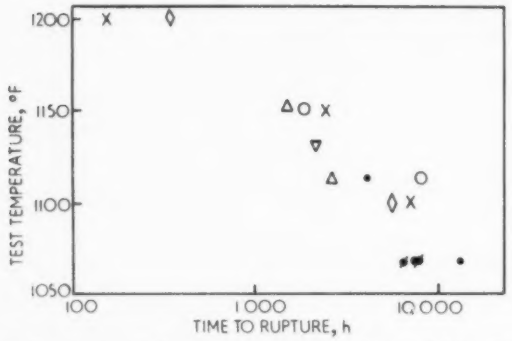
2 *Stress* v. *time to give 1·0% plastic strain and rupture at constant temperature, 1100°F(593°C)*



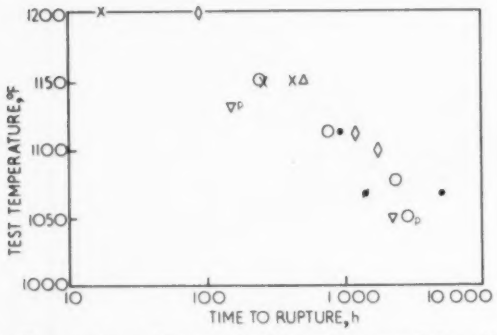
3 *Stress* v. *time to give 1·0% plastic strain and rupture at constant temperature, 1150°F(621°C)*



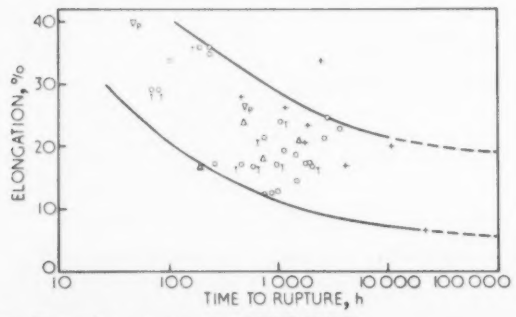
4 *Stress* v. *time to rupture at constant temperature, 1200°F (648°C)*



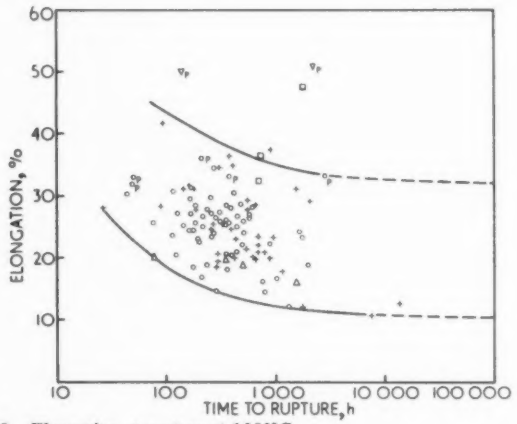
5 *Temperature* v. *time to rupture at constant stress, 5·0 tons/in²*



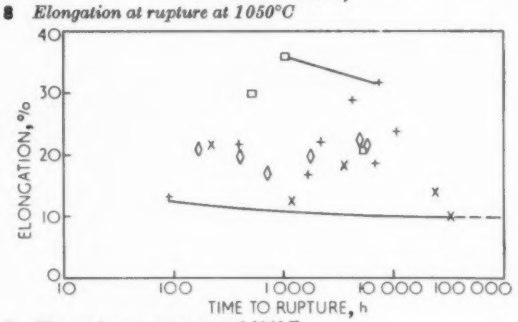
6 *Temperature* v. *time to rupture at constant stress, 7·0 tons/in²*



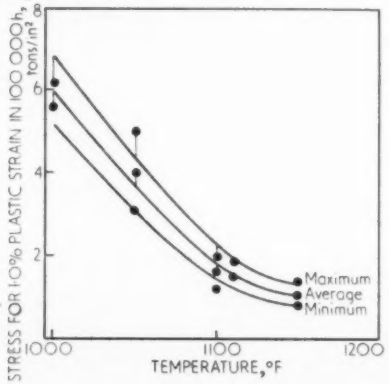
7 *Elongation at rupture at 1000°F (538°C)*



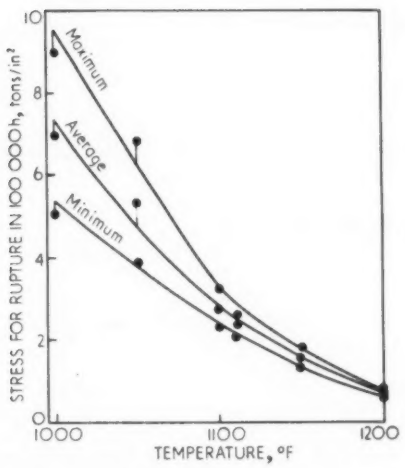
8 *Elongation at rupture at 1050°C*



9 *Elongation at rupture at 1100°F*



10 *Creep properties (1·0% strain) at 100 000 h*



11 *Rupture properties at 100 000 h*

EXTRAPOLATIONS

Extrapolation of the stress *v.* log time curves to 100000 h was carried out and estimates of the stresses to give 1% plastic strain and rupture at this time were made. With more long-time data becoming available, it is becoming increasingly obvious that the relationship between log stress and log time to attain some specific criterion is not linear, but with log stress as ordinate, it assumes a downward curvature. This feature has been taken into account in the extrapolations in Figs.1–4.

Temperature *v.* log time to rupture plots (Figs.5 and 6) were also made at stresses of 5 and 7 tons/in². No extrapolations of these figures were made since there is insufficient data on any one cast to enable reliable slopes of the temperature/log time curves to be established.

The estimated stresses required to cause 1% plastic strain and rupture in 100000 h, i.e. the stresses from Figs.1–4, are shown as a function of test temperature in Figs.10 and 11 respectively. In constructing Figs.10 and 11 smooth average curves were drawn through the available test points and from these smooth curves the design data for this steel was read off. The construction of smooth curves in the stress/temperature plots (Figs.10 and 11) reduces some of the constructional errors incurred in extrapolation. Consequently it is felt that such a procedure gives more realistic standard design data.

TABLE III 100000-h stress data

Temperature, °F	100000-h stress, tons/in² 1·0% Plastic strain max	min	av	Rupture max	min	av
1000	6·8	5·2	6·0	9·5	5·4	7·3
1050	4·4	3·1	3·7	6·3	3·8	4·8
1100	2·2	1·40	1·8	3·2	2·4	2·80
1150	1·4	0·84	1·1	1·8	1·4	1·6
1200	...	...	...	0·78	0·64	0·71

TABLE IV Comparison of stresses obtained with the ASME Boiler Code values

Temperature, °F	ASME Boiler Code values, lb/in²	Stresses derived from UK data, lb/in² 60% Average stress for rupture in 10^5 h	80% minimum stress for rupture in 10^5 h	Stress for 1% plastic strain in 10^5 h
1000	7800	9800	9650	11600
1050	5800	6450	6810	6950
1100	4200	3750	4300	3150
1150	3000	2150	2500	1880
1200	2000	950	1250	...

COMMENTS

The maximum, minimum, and average 100000-h properties for this steel are shown in stress *v.* temperature curves in Figs.10 and 11. The rather high stress value for 1% plastic strain at 1000°F (538°C) is due to the limited data that was available for this criterion. The data that was available related to one of the strongest heats of steel tested. We have therefore recorded what is presumably the top portion of the true scatter band.

More detailed 100000-h stress data are given in Table III. As already indicated, these values have been obtained solely from the log stress/log time plots since it was felt that, due to lack of sufficient data, extrapolations from temperature/log time diagrams would be unreliable. Whilst stress values are quoted for temperatures up to 1200°F, it is not usual to recommend this steel for use much above 1050°F because of its limited oxidation resistance, however, it might be possible to use the steel up to 1100°F provided due allowances are made for oxidation.

Such stresses are general for this composition when given the heat-treatments detailed below. This does not mean that heat-treatment has no effect on the high-temperature properties but rather that the cast-to-cast variations, presumably due to differences in composition and manufacturing history, are greater than the effects of the different recommended heat-treatments for this steel. These recommended heat-treatments are:

(i) full anneal, preferably with a cooling rate of between 15° and 60°C/h through the temperature range 930–650°C. After this treatment tempering is not necessary other than for stress-relieving purposes in which case it should not exceed 700°C

(ii) control anneal and tempered, cool at 400°C/h followed by tempering in the range 650–690°C

(iii) normalize and tempered, cool in still air and temper in the range 650–750°C. In this case it is important that the tempering treatment is not too severe such that it reduces the tensile strength below 36 tons/in².

Whilst it is not the object of this document to evaluate working stresses for this steel the opportunity has been taken to compare such stresses obtained by the methods recommended by the ASME Boiler Code with the ASME Boiler Code values for the steel (*see* Table IV).

It has already been indicated that the design stress at 1000°F based on the plastic strain criterion was abnormally high due to the limited data available.

Corrosion and metallographic study of stainless steels using potentiostat techniques

Vladimír Čihal and Milan Pražák

SYNOPSIS

The availability of potentiostat techniques especially for electrochemical study of stainless steels is indicated. The characteristics of the potentiostat and the significance of potential polarization curves depending on the chemical composition of the alloy and the etching characteristics of their phases are described. The effect of chromium, nickel, and other alloying elements on the corrosion current and properties of stainless steels in regions of activity, transpassivity, and secondary passivity was examined. Differential electrolytic etching at controlled potential can be carried out using the information thus obtained. The potentiostat method can be used to study intercrystalline corrosion. 1632

INTRODUCTION

THE CORROSION RESISTANCE of stainless steels depends first on the type and structure of the alloy and secondly on the properties and concentration of the corroding agent. The ability of stainless steels to become passive is an important property under oxidizing conditions, and the composition limit above which passivity is obtained in stainless steels has analogues in other alloy series. The resistance of Cr–Ni stainless steels to certain environments can be improved by adding further elements such as molybdenum, copper, or silicon.

Detailed study of the structure of stainless steels is important both for metallographic purposes and in the study of corrosion processes. In metallography, the differential etching properties of the individual phases are used in identification, and these same differential properties can give rise to dangerous cases of local or selective corrosion. The processes occurring in metallographic etching are really corrosion processes in reagents with suitable redox potentials, and thus corrosion and etching properties are intimately related.

The method of potential polarization to be described facilitates not only the investigation of the corrosion properties of stainless steels but also the study of the differential etching characteristics of the individual phases.

DEVELOPMENT OF AN INSTRUMENT FOR MAINTAINING AN ELECTRODE AT CONSTANT POTENTIAL

Electrochemical studies of stainless steels can be carried out by measuring corrosion rates either at constant current or at constant potential of the working electrode. At present, the method of polarization of the electrode to a given potential seems to be the most suitable, since by this method, it is possible to record correctly the polarization curves even when these have a negative slope, as occurs in metals able to become passive.[1–3]

Methods of keeping a metal electrode in a solution at constant potential have been known for some time and many instruments for selective cathodic deposition of metals have been constructed for analytical purposes, in which the potential of the electrode was not allowed to fall below a certain value.[4–6] For the same purposes, Hickling[7] used an electronic circuit which also prevented the potential rising above the given value, which he called a 'potentiostat'. Potentiostatic arrangements were also used later for certain special purposes in polarography.[8,9]

Up to the present, the potentiostat method has been used for the study of corrosion phenomena,[10–14] and especially of passivity[12,15] and transpassivity;[16] of cathodic and anodic protection;[17,18] and of intercrystalline corrosion[19] of stainless steels. Its use for differential electrolytic etching for metallographic purposes has also been recommended.[16,20–23]

EXPERIMENTAL METHOD

Characteristics of the potentiostat

An instrument to be used for potential polarization of electrodes must have low internal resistance of the polarizing source and react quickly to changes of the potential of the working electrode if accurate polarization curves are to be obtained.

On this basis, the electronic potentiostat[3] constructed consists of two stages. A dc amplifier amplifies deviations from the required potential of the working electrode as determined by the setting of the potentiometer and controls the current in the terminal stage, which is used to polarize the electrode (*see* Fig.1). The potential of the working electrode E_1 is controlled with reference to a saturated calomel electrode and its potential is independent of the potential of the inert electrode E_2 (platinum) or of the potential gradient in the electrolyte. A constant-current generator is included in the circuit to ensure that the terminal stage operates over the centre of its characteristic and to allow the working electrode to be polarized either positively or negatively.

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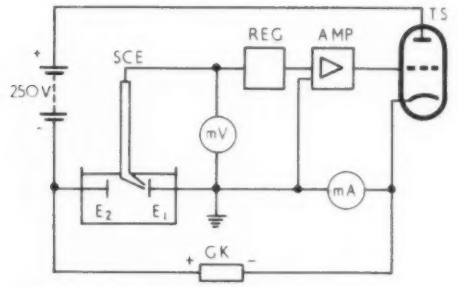


1 *Circuit of potentiostat*

The potentiostat used can keep the potential of an electrode constant to within 2–3 mV over 15 min and can deliver currents of up to 100 mA in either direction, or 200 mA in one direction only. The internal resistance of the instrument is 0·3 Ω and its input impedance is high enough to allow use of a high-resistance reference electrode with a Luggin capillary (resistance of several thousand Ω). When used in conjunction with a sawtooth waveform current generator,[24] polarization curves can be obtained and displayed on a cathode-ray oscillograph and recorded photographically. The potential of the working electrode is measured by a valve voltmeter and the polarizing current by a milliameter.

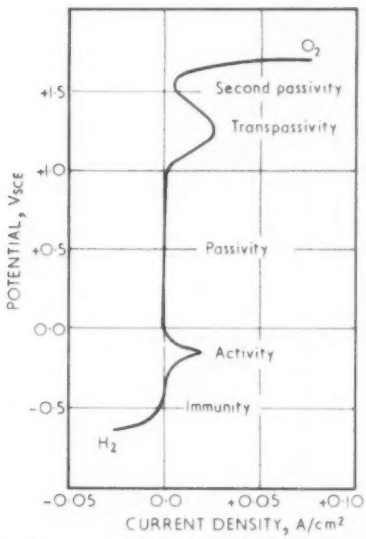
Since electrode reactions take a finite time to establish steady-state conditions, the shape of the polarization curve depends to some extent on the rate of change of potential of the working electrode and in reactions where the polarization curve has a negative slope, the whole curve may be badly distorted. The effect is largely eliminated by varying the potential slowly (e.g. 1 V/min) and by recording polarization curves in both directions. During the automatic recording of polarization curves in $5\%H_2SO_4$ to be described, the rate of change of potential was $dE/dt = 0{\cdot}017$ V/s. The potential scale was calibrated from a standard Weston cadmium cell, and a milliameter with a precision of 1% was used to calibrate the current scale.

Significance of potential polarization curves

The reactions taking place at a stainless-steel electrode are determined by its potential, which may be either an equilibrium potential or may be governed by polarization by an external current.

Since the position and shape of the polarization curves of an alloy depend on the solution composition and temperature, as well as on the chemical composition of the alloy and the type and number of different phases present, these curves can be used to study the corrosion behaviour of the alloy, as well as the etching characteristics of the phases present in the alloy. It is possible to predict the approximate shape of the curve from the composition of the alloy and the solution in which it is immersed, and conversely, the characteristics and composition of the alloy can be judged from a knowledge of its polarization curve.

For instance, from the polarization curve of 18–8 steel in $5\%H_2SO_4$ (Fig.2), potential regions in which anodic solution takes place (activity and transpassivity) can be identified, and also others in which the steel is immune or passive. As long as there are no interfering redox reactions in the solution, the current



2 *Polarization curve of 18–8 steel with composition 0·05%C, 1·5%Mn, 0·62%Si, 18·48%Cr, 9·34%Ni (solution treatment 1050°C, 30 min, WQ)*

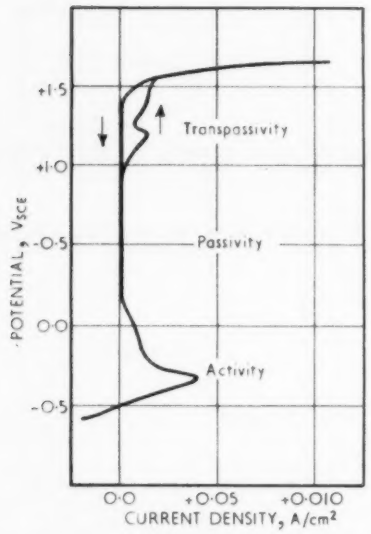
used to polarize the working electrode can be equated to the velocity of the anodic reaction by Faraday's law. In the active region, solution of the steel takes place and ions with the lowest valency are formed. At potentials high enough to give passivity, this reaction stops and a passive layer is formed on the steel. The current flowing through the electrode is very low and corresponds to the rate of corrosion in the passive state. The upper limit of the passive region is the region of transpassivity, where in an 18–8 steel, the Cr^{3+} component of the passive layer begins to be oxidized to soluble Cr^{6+}. Thus the protective properties of the passive layer are destroyed and solution of the steel takes place.

When the potential is raised further, the current decreases again and secondary passivity occurs. This passivity is incomplete and the current decreases to only $\frac{1}{3}$ or $\frac{1}{10}$ of its value at the transpassivity maximum. Masing, Heumann, and Jesper[25] first observed this phenomenon with Fe–Cr alloys. Secondary passivity seems to occur both with ferritic Cr steels and the 18–8 steels, and the authors results indicate that it depends on the composition and structure of the steel.

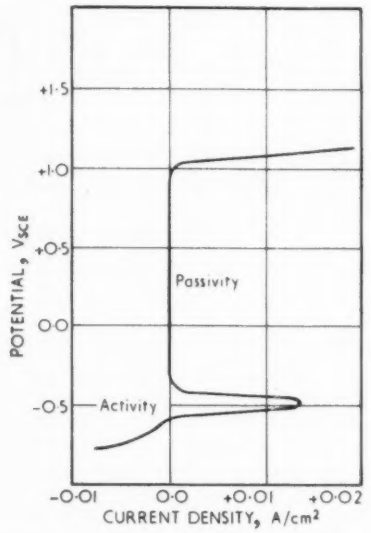
EXPERIMENTAL RESULTS ON SOME ALLOYS

Effect of Cr content on corrosion current in regions of activity and transpassivity

As the chromium content of the alloy increases, corrosion current in the transpassivity region increases considerably and the current minimum in the secondary passivity region disappears. In alloys with up to 16%Cr, a certain amount of current, corresponding to oxidation, is observed in the transpassivity region, but this occurs only when scanning in one particular direction and the passive layer is resistant to further oxidation. This appears as an apparent irreversibility in the polarization curve when recorded in opposite directions (Fig.3).



3 *Polarization curve cast alloy of iron with 13·9%Cr*



5 *Polarization curve of cast* Fe–Cr *alloy with 43%Cr*

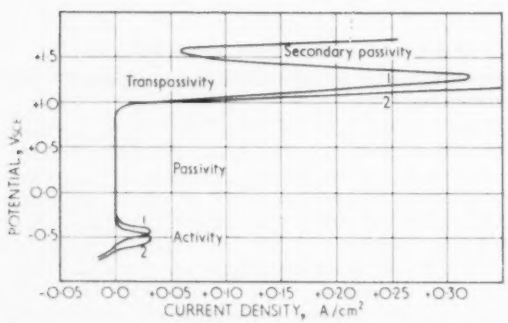
In alloys with a chromium content greater than 18%, the polarization curve in the transpassivity region is reversible. At chromium contents of between 18% and 30%, the current decreases sharply just before the potential for oxygen evolution is reached and secondary passivity occurs. Secondary passivity has not been observed in alloys containing 35%Cr (Fig.4), while alloys with more than 35%Cr behave like pure chromium (Fig.5).

Thus the behaviour of Fe–Cr alloys in the transpassivity region is characterized in two comparatively sharp compositional regions of 16–18%Cr and 30–35%Cr[32] and these experimental results are in complete agreement with theoretical conclusions about the composition of alloys on which spinel passive layers would be formed.[26] The theoretical compositional values are 16·7 and 33 at-%Cr, corresponding to 15·5 and 30·7 wt-%Cr respectively. Changes in behaviour at these compositions of Fe–Cr alloys could not be predicted by the well known Tamman's rule, which confirms the view that the electrochemical reactions occurring in the transpassivity region involve the passive layer and the solution and not the metal itself.

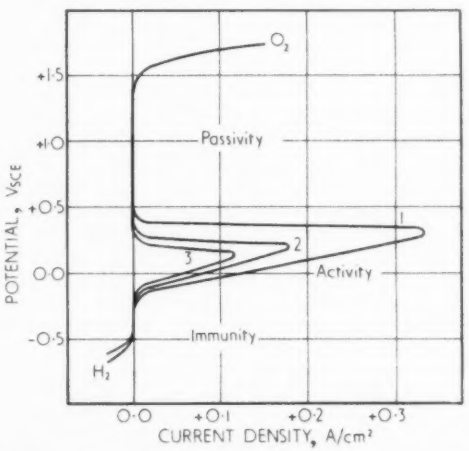
In the active region, the maximum corrosion current decreases with increasing chromium content up to 18%, and the addition of chromium also pushes the active region to more negative potentials (Figs.2 and 4), in agreement with the lower nobility of chromium compared with iron. The gradual change from activity to passivity in an Fe–13%Cr alloy (Fig.3) seems to be connected with the transition at this composition from 'iron passivity type' to 'chromium passivity type'.[27]

Effect of nickel on corrosion current

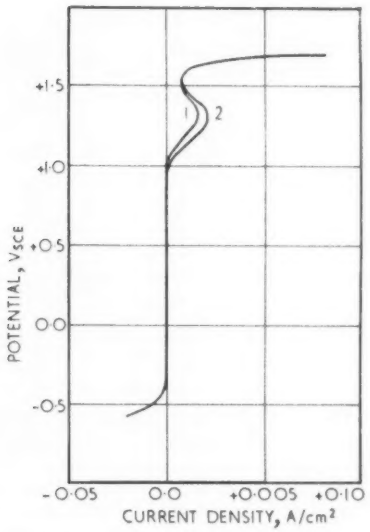
The transpassivity region is of practical importance only for chromium and its alloys, since for iron and



4 *Polarization curve of iron alloys with* (1) *30·96%Cr*, (2) *35·50%Cr* (*780°C, 30 min, AC*)



6 *Polarization curve of iron alloys with* (1) *20%Ni*, (2) *36%Ni*, (3) *42%Ni*



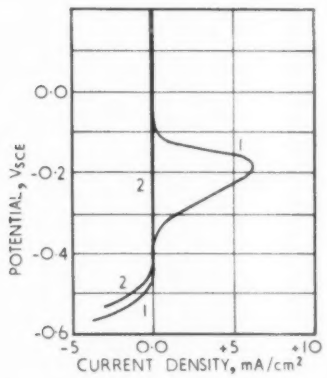
7 *Polarization curve of steels* (1) *18–8* Mo *with composition* 0·1%C, 1·2%Mn, 0·74%Si, 18·2%Cr, 10·5%Ni, 2·5%Mo; (2) *18–8* Ti *with composition* 0·08%C, 1·18%Mn, 0·88%Si, 18·34%Cr, 9·2%Ni, 0·21%Mo, 0·8%Ti *(solution treatment 1050°C, 30 min, WQ)*

Fe–Ni alloys, the transpassivation potential is so high that oxygen is evolved before this potential is reached.

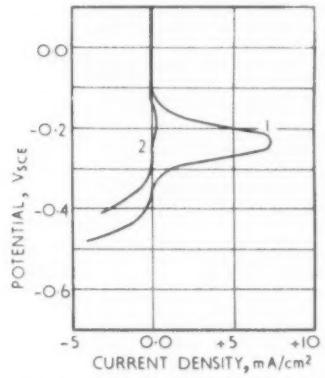
Addition of nickel decreases the maximum corrosion current in the active region, as is evident from the polarization curves for iron alloys containing 20, 36, and 42%Ni (Fig.6).

Influence of some alloying elements on the corrosion properties of 18–8 steels

The corrosion resistance of stainless steels can be improved by the addition of further elements, such as molybdenum, copper, titanium, niobium, and silicon. Molybdenum, as a higher member of the chromium group, improves corrosion resistance not only in the passive state but also in the active state, as is shown



8 *Activity region of polarization curves of 18–8* Ti *steel with composition* 0·09%C, 0·95%Mo, 0·83%Si, 18·24%Cr, 9·5%Ni, 0·11%Mo, 0·35%Ti *after solution treatment* (1) *1050C, 30 min, WQ*, (2) *1250°C, 1 h, WQ*



9 *Activity region of polarization curves of 18–8* Nb *with composition* 0·09%C, 0·94%Mn, 0·75%Si, 18·06%Cr, 9·28% Ni, 0·19%Mo, 1·03%Nb, *after solution treatment* (1) *1050°C, 30 min, WQ*, (2) *1250°C, 1 h, WQ*

by the lowered corrosion current in the active region for an 18–8 Mo steel (Fig.7). Resistance to hot H_2SO_4 is best obtained by increasing both the nickel and molybdenum contents (or even by the addition of copper), rather than by increasing the molybdenum content alone[28] in confirmation of the experimental results obtained by Edeleanu.[23]

Stabilization of stainless steels by the addition of titanium or niobium to prevent either intercrystalline corrosion or embrittlement of the creep-resisting steels owing to carbide precipitation at the grain boundaries also has an effect on corrosion in the active region. The ratio of titanium or niobium content to carbon content is the factor controlling the effectiveness of stabilization, but amounts of titanium higher than the stoichiometric proportion in solution in the austenite cause a decrease of corrosion current in the active region, as shown in Fig.7 for an 18–8 Mo steel. The curves for a steel with the Ti : C ratio about 4 : 1 after a solution treatment of 1250°C[29,31] confirm this effect of titanium in solid solution (Fig.8) and a similar effect can even be observed with an 18–8 Nb-stabilized steel (Fig.9).

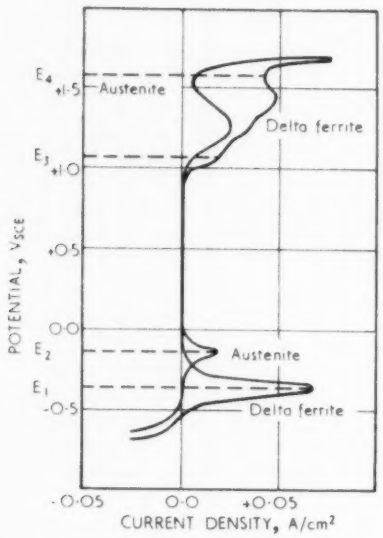
APPLICATION OF POTENTIOSTAT TECHNIQUES IN METALLOGRAPHY

Differential electrolytic etching at controlled potential

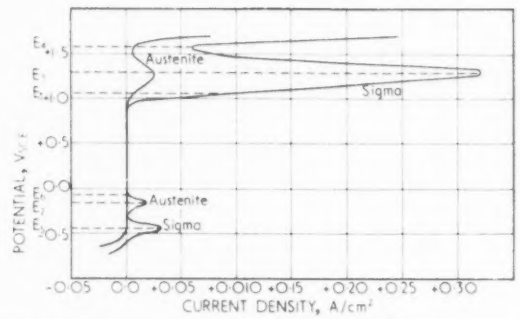
In an alloy containing two or more phases, each phase has a certain characteristic polarization curve and by comparing these, it is possible to choose a potential at which one particular phase is preferentially attached,[30] and for effective differentiation of the phases it is important that the difference in corrosion rates of the phase under study and of the other phases present should be as large as possible at the chosen potential. This difference is termed the differentiation ratio D[21,22] given by

$$D_A = \left(\frac{i_A}{i_B}\right)_E$$

where i_A and i_B are the values of current per unit area of the phases A and B at the potential E. The differentiation ratio is independent of the proportion of the two phases present.



10 *Polarization curves of austenite or delta ferrite, with potentials for selective etching*



11 *Polarization curves of austenite and sigma phase with potentials for selective etching*

To choose a potential suitable for selective etching of a given phase in an alloy, it is necessary to have polarization curves of the individual phases, but it is often difficult to obtain electrodes composed of one homogeneous phase, and secondary phases sometimes affect the polarization curves of nominally 'pure' phases.

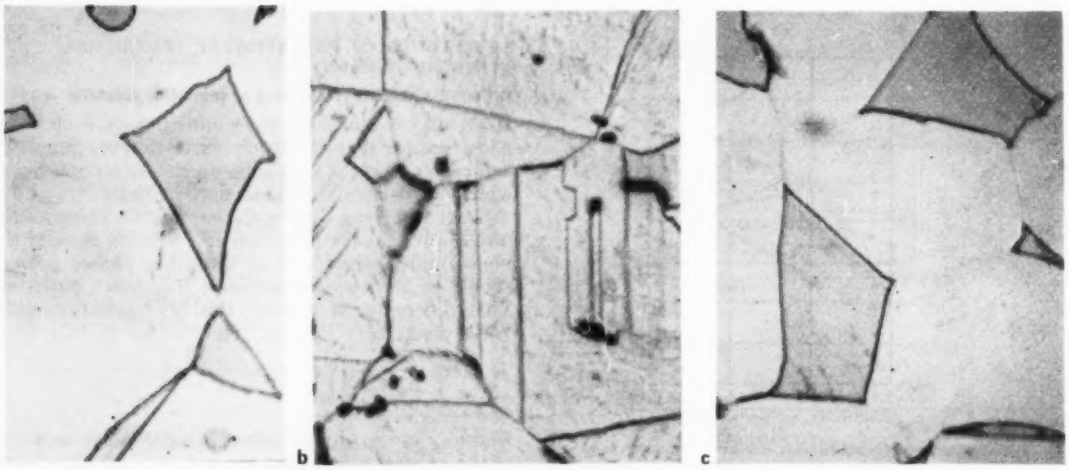
Etching of stainless steels

The structure of 18–8 stainless steels depends not only on the perfect balance of the chromium and nickel contents but also on the proportion of further elements favouring the formation of austenite or delta ferrite, such as nitrogen, carbon and manganese, or titanium, niobium, molybdenum, and silicon.

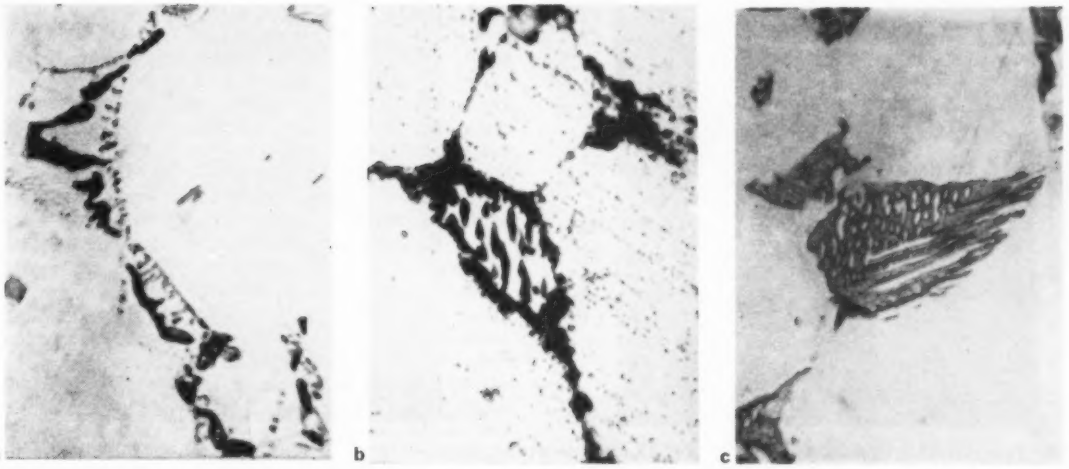
For instance, the addition of titanium to an 18–8 steel in excess favours the formation of delta ferrite, indirectly by combining with carbon and nitrogen and so limiting their tendency to form austenite, and directly as a ferrite-forming element when present in excess in solid solution. Delta ferrite is not stable at temperatures lower than 800°C and decomposes giving carbides, austenite, and sigma, which are different not only in structure, but also in chemical composition and particularly in chromium content. Accordingly, their differentiation has been studied in the stabilized steel, of the composition given in Fig.8, by means of electrolytic etching at controlled potential. The hot-worked steel after solution treatment for 1 h at 1 250°C (WQ) contains about 6% of delta ferrite.[33]

Sections of this steel were prepared by standard metallographic techniques, using mechanical polishing. The surface area of the sections was 1 cm² and during etching they were mounted with the surface vertical. The etching solution was 5% H_2SO_4, to which 0·1 g/l. NH_4CNS was added. This accelerates the achievement of dynamic balance of the various reactions taking place by its activating effect.

In accordance with the considerations given, the differentiation of phases is based primarily on their differing chromium contents. To obtain polarization curves of the individual phases, we have used curves obtained from Fe–Cr alloys of similar composition,



12 *Measured 18–8 Ti steel after solution treatment 1 250°C, 1 h, WQ, etched (a) at potential $E_1 = -0{\cdot}35V$, 60s, (b) at potential $E_2 = -0{\cdot}15V$, 30s, (c) at potential $E_3 = +1{\cdot}57V$, 3 min* × 1600



13 *Measured 18–8 Ti steel after heat-treatment 1250 C, 1 h WQ + 650 C, 72 h, AC, etched (a) at potential $E_4 = +1{\cdot}57$V, 20 s, (b) at potential $E_2 = -0{\cdot}15$V, 25 s, (c) at potential $E_1 = -0{\cdot}4$V, 60s* × 1600

e.g. for ferrite (22–25%Cr[34,35]) an Fe–Cr alloy 24·3%Cr, 0·08%C was used; for sigma(26–30%Cr[34–36]) an alloy 30·9%Cr, 0·06%C was used. The absence of nickel (about 5–7% in delta ferrite[34,35]) has no pronounced effect on the position of the characteristic regions of the curve on the potential axis and only gives a rather higher rate of anodic solution in the active region. For the polarization curve of austenite, we have used the curve for an 18–8 steel shown in Fig.2.

Etching in the active and passive regions

As the chromium content is raised, the active region and the passivation potential become more negative. Thus, by comparing the polarization curves for austenite and delta ferrite (Fig.10) and for austenite and sigma (Fig.11), we can choose an etching potential so high that virtually only one phase is selectively attacked.

For instance, austenite can be distinguished by etching in the active region at a potential $E_2 = -0{\cdot}15$V for 20–120 s (Fig.12*b*), while the ferrite or sigma phases respectively are preferentially etched at lower potentials, E_1 (−0·35V) up to E_5 (−0·45V) Fig. 12*a*). At potentials more positive than the passivation potential, etching of chromium-rich phases does not take place, but if there are areas less readily made passive, these can be attacked at potentials in the region of passivity for the austenite grain in which they lie. We have used this method to etch grain boundaries deficient in chromium in an 18–8 steel sensitized to intercrystalline corrosion, at a potential of −0·1V for 3 min.

For etching in the active and passive regions, it is advisable to activate the specimens beforehand at −0·8V.

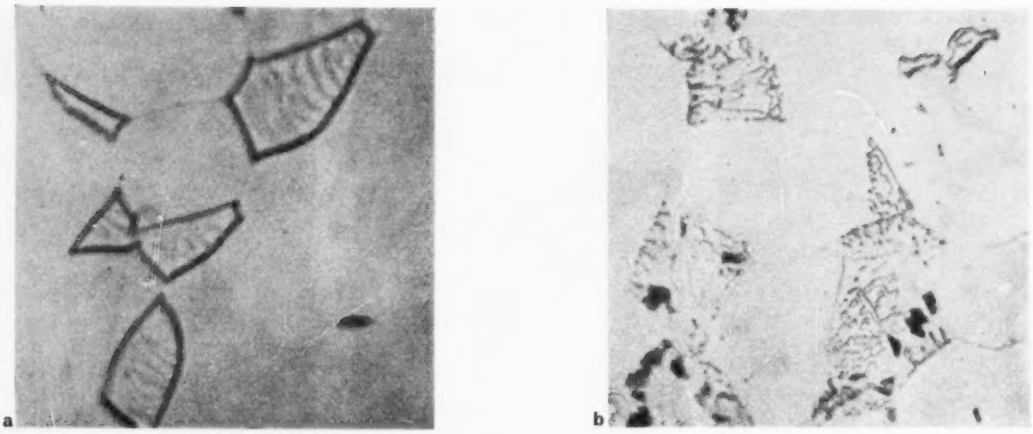
Etching in the regions of transpassivity and secondary passivity regions

The height of the corrosion current maximum in the transpassivity region depends on the chromium content of the individual phases, as has been observed for

TABLE I Potentials for selective etching of phases in 18–8 steels

Solution	$20\%H_2SO_4$*		$5\%\ H_2SO_4 + 0{\cdot}1$ g/l. NH_4SCN				
Etched phase	V_{sce}	Etching time	V_{sce}	Etching time	D, for etched phase	Potential from Figs.6 and 7	Remarks
Delta ferrite	−0·45	1 h	−0·35 −0·40	60–250 s	40	E_1	Etched in the active region
Sigma phase	...	...	−0·40 −0·45	60–150 s	100	E_5	" "
Austenite	−0·35	1 h	−0·15 −0·20	20–120 s	100	E_2	" "
Austenite grain boundaries	...	...	−0·10	1–3 min	...	E_6	At beginning of passivity
Delta ferrite	+1·05	3–5 min	...	...	...	E_3	At beginning of transpassivity
Delta ferrite Sigma	...	...	+1·57 +1·59	20 s–6 min	11	E_4	In secondary passivity region
Sigma phase	...	...	+1·30 +1·35	...	11	E_7	In transpassivity region
Martensite	−0·50	...	...	...	...	...	In active region
Activation	...	...	−0·70 −0·80	10 s	...	...	...

* *See* ref.20



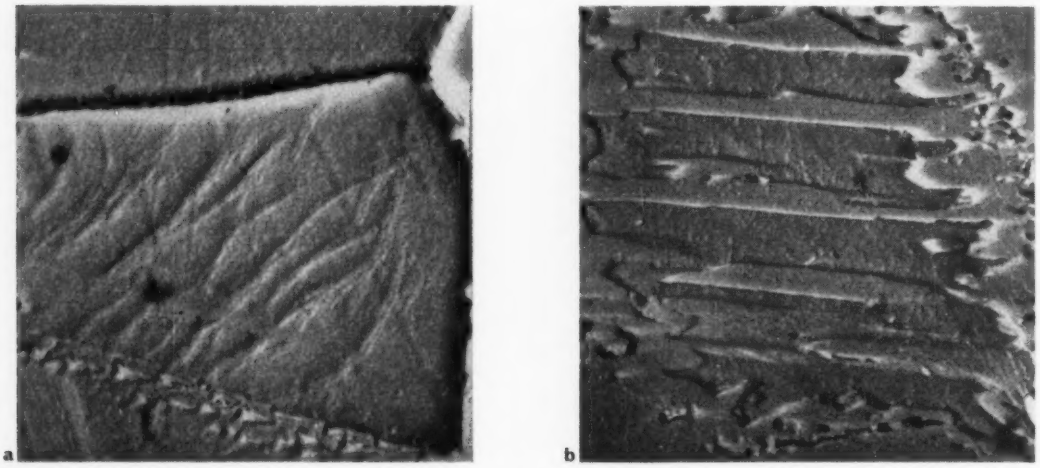
14 *Transformation of the delta ferrite in 18–9* Ti *steel, temperature treatment 1250°C, 1 h, WQ, and (a) 650°C, 30 min, etched (5%H_2SO_4 in region of transpassivity 86s, (b) 650°C, 72 h, AC etched (5%H_2SO_4 in region of transpassivity 42 s)* × 1600

alloys with 18–43%Cr. From Figs.10 and 11 phases with higher chromium can be differentiated from austenite by using the secondary passivity region at a potential of $E_4 = +1{\cdot}57$V, where phases richer in chromium show a lower decrease in corrosion current and are therefore etched more quickly than austenite with 18%Cr. In this potential region, the degree of differentiation seems to be relatively higher than at the beginning of the transpassivity region (Fig.12*c*). Austenite is, of course, also slightly attacked at a rate corresponding to the small current on the polarization curve. The secondary passivity region for austenite is suitable for the differentiation of higher-chromium phases (sigma) from secondary austenite, ferrite, and carbides (Fig.13*a*). Secondary (or 'new') austenite naturally differs in its chemical composition from the original austenite, and is etched intensely after 25 s in the activity region at $E_2 = -0{\cdot}15$V (Fig.13*b*), while at $E_1 = -0{\cdot}4$V, delta ferrite and sigma are etched well after 60 s (Fig.13*c*). In the transpassivity and secondary passivity regions, activation of the steel before etching is unnecessary.

Edeleanu[20] distinguishes delta ferrite and sigma phase from austenite by etching in 20%H_2SO_4 using the potentiostat, and the potentials he uses are compared with those of the present authors in Table I.

Transformation of delta ferrite in 18–9 Ti steel

In a recent paper,[16] the authors used etching in the transpassivity region, at the same time recording the polarization curve of the specimen, either in both directions (80 s) or a more intensive etch in one direction only (42 s), to follow the transformation of delta ferrite in an 18–8 Ti steel (composition given in Fig.7) after solution treatment for 1 h at 1250°C (WQ). On a steel specimen heated in addition for 30 min at 650°C (AC), changes already beginning on the γ/δ boundaries and even the ferrite formed inside were visible after etching. On the boundaries of both phases, carbides of chromium and titanium are precipitated[38] and as a result, delta ferrite transforms to austenite. Inside the delta ferrite, features characteristic of the first stage of transformation are formed (Figs.14*a* and 15*a*) and

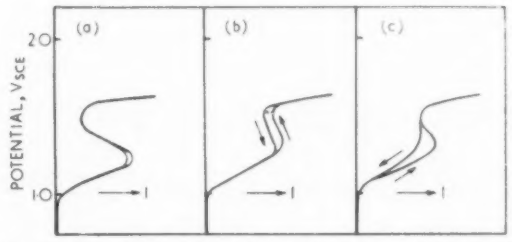


15 *(a) and (b) Electron micrographs of transformed delta ferrite from the etched specimens for Fig.14a and b* × 10000

observation after 72 h at 550°C (AC) and 72 h at 650°C (AC) suggests that these are features of the first stage of new austenite (as stated by Kuo[39]). After these periods of heating, ferrite begins to be transformed into two special phases, i.e. less intensively etched lamellae of austenite with a lower chromium content in contrast to the chromium content of the original delta ferrite, and an intensively etched phase of untransformed delta ferrite (eventually becoming sigma phase) with higher chromium content, along with fine precipitates of carbides (Figs.14*b*, 15*b*).

Recognizable changes also occur in the polarization curves during the ferrite transformation. The curve is irreversible and the ability to achieve secondary passivation decreases (Figs.16*a*, *b*, and *c*). The lower current on the curve recorded with falling potential is explained by supposing that during the first potential scan with rising potential, the chromium-rich phase was dissolved from the surface of the steel. The presence of this phase would limit the fall in corrosion current corresponding to secondary passivity of the steel.

Thus, electrolytic etching under controlled potential overcomes some of the failings of conventional etching techniques[39] and, in addition, the changes in the characteristics of polarization curves brought about by the presence of a chromium-rich phase in the structure indicates a promising method for the electrochemical study of metallurgical structures.



16 *Transpassivity region of the polarization curve from 18–8 Ti after treatment at 1250°C, 1 h, WQ + (a) 650°C, 30 min, AC, (b) 550°C, 72 h, AC, (c) 650°C, 72 h, AC*

SUMMARY

The results of experiments so far carried out confirm the controlling effect of potential on the corrosion behaviour and etching characteristics of the stainless steels and their structural phases. When the relationships between the characteristics of alloys, their individual phases and the shape of their polarization curves are known, it is possible to choose a potential for etching suitable for differentiation and identification of phases of lower or higher chromium content (sigma and delta ferrite, and austenite). Although this corrosion and metallographic method requires more complex instrumentation, it allows etching and study of stainless steels under conditions not otherwise obtainable. It is also important that the theoretical principles of the method are at the same time the basis for the study of selective structural corrosion.

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Electric soaking-pit practice at Appleby-Frodingham using controlled-cooling methods

P. Charlesworth

SYNOPSIS

An endeavour has been made in the soaking and slabbing-mill practice at Appleby-Frodingham, to utilize to the full, the high heat content of the ingot as received from the melting shop. This has been done by using fast track times, a suitable soaking pit maintained at a constant temperature, and rolling at predetermined times. The soaking pit used was an electric soaker with a single trough coke resistor, the first of its type to be installed in this country. The fuel consumption, equated to therms/ton for comparison with gas-fired soakers, is remarkably low. The running maintenance is negligible. 1650

AN ELECTRIC SOAKING PIT came into production at the Appleby-Frodingham Steel Company's works in May 1957. Although electric pits had been operating extensively as heating pits, especially in Scandinavia, this particular pit was the first of its type to be built with the object of soaking by cooling rather than by heating.

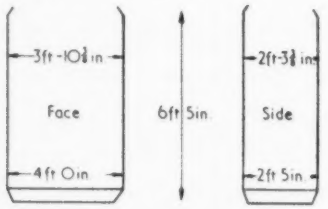
It has been recognized for many years that the fast track times obtained at Appleby and sizeable ingots such as the 10-ton ingot give favourable conditions for soaking ingots with little or no fuel. Before describing the electric soaker itself, a preliminary examination of the necessary steel supply, and the experiences gained from the operation of the gas-fired single cell* (described later) give an idea of requirements in practice.

FLOW OF SUITABLE HOT INGOTS FROM THE MELTING SHOP

The average tonnage of ingots, before May 1957, rolled each week at the Appleby soakers in 17 shifts amounted to 13300 tons of which 2700 tons were cold charged and charged at week-ends. The balance of those rolled was made up of ingots as follows:

1800 tons	15-ton ingots
700 ,,	10-ton brick tops
7800 ,,	10-ton balanced ingots
300 ,,	6-ton ingots

The suitable ingots are the 10-ton balanced type, with measurements as shown:



The normal size of ladle made at the Appleby shop in 10-ton moulds produces eight 10-ton ingots. These ingots, with a tap-to-charge time of 2 h, can be got ready for rolling in a gas-fired soaking pit in 1½ h, giving a tap-to-roll time of 3½ h. A reasonable time from one charge to the next, giving adequate time for charging and rolling the eight ingots, would be 2½ h, or 3 charges per 8-h shift.

Given a soaker holding 8 ingots and a supply of suitably hot ingots, at the rate of 3 charges per shift, then a production of 4000 tons is possible in a 17-shift week. It will be seen from the hot ingots received that 4000 tons is available, and it should be added that there is no difficulty at all in receiving them at the soakers within 2 h of tapping. When considering melting shops with large furnaces, producing 3 or 4 ladles at a tap, which may or may not be of the balanced-type ingot, some degree of irregularity can be expected. This irregularity was examined over a long period, the result giving an average number of possible charges of 37, amounting to about 2700 tons per week.

Experience gained from the single cell

It follows from the single cell that a soaker to give the best results should comply with the following conditions; the temperature of the soaker should be constant at a figure best suited to the particular soaker-bay practice, the atmosphere surrounding the ingots should be as far as possible static, ingots should be isolated from each other to give standard cooling rates, there should be no hollows in the soaker floor as this tends to give a cold bottom to the ingot, if hot ingots must lean against the soaker wall then they should touch as small an area as possible, preferably well above the middle of the ingot. This will avoid the danger of a hot spot being created.

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The author is assistant plate mill manager at Appleby-Frodingham.

* A. JACKSON, N. H. TURNER, and R. C. WALTHEW: *JISI*, 1958, **188**, 114–118.

ELECTRIC SOAKER

The electric soaker consists of 8 cells, each cell capable of holding one 10-ton ingot. Down the centre of the furnace, with four cells on either side passes a single resistor in the form of a silicon carbide trough filled with petroleum coke. This resistor supplies the heat, current being introduced to the troughs through graphite electrodes held in water-cooled electrode holders.

The arches on three sides of each cell are built of semi-silica brick. The remaining side on which rests the ingot is also made of semi-silica, suitably backed with insulating bricks. The ingot does not rest against the wall, but against a corbel made of dense high-alumina firebricks; this corbel continues round to the walls supporting the arches.

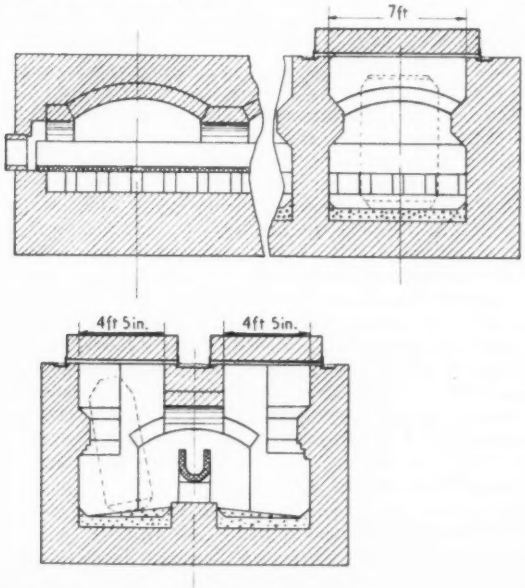
The bottom is made of 5 in. of rammed dolomite and inclined towards the trough, causing the ingot to tilt against the corbel. Beneath the dolomite is a course of chrome–magnesite, several courses of firebrick, and a substantial amount of backing insulation (*see* Figs. 1 and 2).

The eight covers, one to each cell, are substantially lined with firebrick hangar and filler bricks; they sit in sand seals so that when all are seated, the soaker is one large enclosed space. The openings in the central arch through which coke is fed to the trough below are covered when not in use. These covers have their own sand seals.

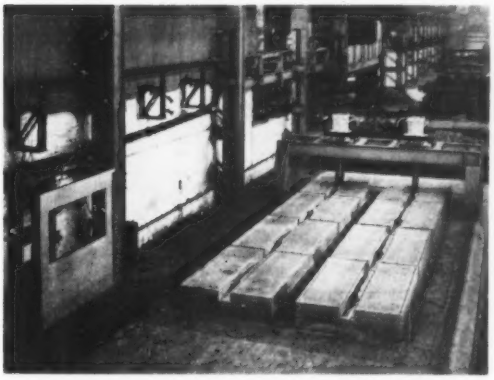
It will thus be seen that the two primary features of the design are a high degree of insulation and a structure which prevents the entry of atmospheric air.

The cover lifting machine is pneumatically driven and manually operated.

The input to the soaker is supplied by a 950-kVA oil-filled, naturally cooled transformer, and regulated by a motorized on-load tap changer. The power is maintained within any of three bands, designated full power, intermediate power, and low power, by control relays which are located within the control panel, and which are manually set.



1 *General layout of electric soaking pit*



2 *Electric soaker on completion*

Deviations from the pre-set temperature are automatically corrected for by the temperature controller selecting the appropriate power level. If it is desired, the temperature controller can be cut out and a power level selected manually.

The resistance of the trough depends on temperature, the state of the coke in the trough, and the age of the trough. Inasmuch as the power controllers maintain the power within a prescribed band they compensate for these factors and also for fluctuations in the supply voltage. The resistance of the trough decreases with time, and it is observed that the range of the voltage taps used decreases as the life of the trough progresses. For the initial operation the double windings of the transformer were connected in series and at a certain point when the trough resistance becomes lower it is necessary to connect these windings in parallel to provide a lower series of voltages.

The circuit breaker, which is the on–off switch for the soaker, is located in a switchgear room near the transformer room. It may be operated either locally or at the panel. The control circuit is arranged so that the circuit breaker will trip on any fault, either thermal or electrical, so that the soaker may be left unattended for long periods with complete safety. The nature of any fault is indicated by a flag or light on the panel.

On the panel are a series of lights, only one of which is alight at any time, showing the state of the soaker. These are: manual operation, showing that the soaker is not on automatic control, and cannot be left indefinitely; high, intermediate and, low power levels, indicating the temperature level in the pit and hence the state of the charge; circuit breaker open, showing that the soaker is off.

On manual control the power can be changed by the raise and lower buttons situated on the panel.

Power input to the soaker is shown on the kilowattmeter and the tap number on the tap-position indicator.

It is arranged for blast-furnace gas at about 40 ft^3/h to be introduced into the pit to provide a slightly reducing atmosphere, and to consume any excess oxygen which enters the soaker when the covers are lifted. The rate of input is controlled manually at a point near the panel, and indicated on a rotameter. A solenoid valve is included in the system so that should the soaker temperature drop below about 700°C the gas supply is shut off.

TABLE I Electric soaker ingot index

Finish strip to charge time of 1st ingot, min	Tap to finish strip time, min 45	50	55	60	65	70	75	80	85	90	95
	Tap to roll time (h and min) = index										
50	2 50	2 50									
45	2 55	2 50	2 50								
40	3 05	3 00	3 00	2 55							
35	3 20	3 15	3 05	3 00	2 55						
30	3 40	3 30	3 20	3 15	3 00	2 55					
25	3 55	3 45	3 40	3 30	3 20	3 10	3 00				
20	4 15	4 00	3 55	3 45	3 35	3 25	3 15	3 00			
15	4 25	4 20	4 15	4 05	3 50	3 40	3 30	3 25	3 15		
10	4 40	4 35	4 30	4 20	4 10	4 00	3 50	3 40	3 30	3 15	
5	4 55	4 50	4 45	4 35	4 25	4 15	4 05	3 55	3 45	3 30	3 15

1 240° C pit temperature

These index times depend on the ingot letter as below:

	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	
Tap to finish strip time	−10	−10	−10	−5	−5	0	0	0	min
Strip to first ingot charge time	+10	+10	+10	+5	+5	0	0	0	

A 'working' index should be worked out on the first two ingots charged, the longest time being the index, e.g.

Tap to finish strip	=	70	Index for *A* ingot	=	60	*D*	= 65	*G* = 70
Strip to first charged	=	10			20		15	10

It will be noted from this description of the electric soaker that the conditions for heating ingots with little or no fuel are largely met, i.e. ingots are placed in uniform-temperature enclosures, separated from each other, and leaning on a corbel wall; the atmosphere can, if necessary, be largely static; the control system precisely maintains a set working temperature.

Operation of the soaker in practice

In view of the essential feature of the design of this soaker, i.e. a power input not greatly in excess of the standing loss, 'mixed-bag' charging was out of the question. Previous experience with the single-cell cooling pit had shown that tap-to-charging times of under 100 min would be necessary. It was decided to operate the soaker at 1240°C.

Charging ingots with up to 100 min tap-to-charge time

At Appleby-Frodingham certain times are recorded concerning every cast of steel that is made, namely, the tapping time, the finish stripping time of the cast, and the commence charging time. Operating personnel were well used to these times in standard practice so an index table was evolved incorporating these figures as shown in Table I. It will be seen that certain simplified safeguards were added, as the heat content of ingot H is higher than that of ingot A.

It might be stated here that the actual finish teem time and strip time of each ingot would be the logical times to take, but it was felt that this would complicate the index unnecessarily for the operative. The standard times adopted in the index tables were found to be quite adequate and completely successful.

When using the index table, the best charging times were found to be 90–100 min, these giving maximum production rates with minimum kWh consumed.

If casts were stripped and received at the soakers very early after tapping, it was usual to delay charging until about 90 min had elapsed after tapping. However, charging early would take place if the next suitable cast to charge was not available for several hours, and other soakers had to be drawn and emptied over the next 2 h or more. The extended soaking time of ingots charged early lessens the potential throughput of the soaker, but it is a means of saving power and justifiable in the case mentioned.

It was, and is, practice to leave power on when charging ingots. Charging the soaker to full capacity (eight 10-ton ingots) takes about 10 min. When the last ingot is charged power is switched off and remains off until the calculated time arrives for drawing the first ingot; power is then switched on and the first ingot taken out and rolled. Power is left on from this time until the soaker is emptied and charged again.

Charging ingots with 105–120 min tap-to-charge time

It was soon realized after a few days of production that the tap-to-charge time might possibly be extended if some power were left on during the actual soaking time of the ingots. After a few experiments another table was evolved enabling casts with a tap-to-charge time of up to 120 min to be used, still operating the soaker at 1240°C (as shown in Table II).

In practice an anlysis of tap-to-charge times showed about 14%, needing varying degrees of power as shown:

Min	70	75	80	85	90	95	100	105	110	115	120
	Without power							With power			
% of heats charged	1·5	3·5	4·0	17	24	23	13	6·5	3·5	2·5	1·5

The average kWh/ton was 32, or about 1·1 therms/ton.

A typical hot-charged cast of about 90 min tap-to-charge time would, on the completion of the charging operation, lower the temperature of the soaker some 70°C. The temperature, power being off, would gradually rise over the next 80–100 min and tend to level out about 10°C below the operating temperature a few minutes before drawing was due to begin.

By the time the last ingot was drawn, the soaker had recovered its temperature. With casts charged late and requiring power, the temperature never recovered and casts would be rolled with soaker temperatures as low as 1200°C, but quite satisfactorily. When the temperature of the soaker was below 1200°C at the start of charging it became necessary to have a cast charged in a range requiring no power, otherwise it would not have rolled satisfactorily.

Standing heat losses

The foregoing conditions are brought about by the characteristics of the soaker and determined by the standing heat losses. The standing heat losses were

obtained by maintaining the soaker at 1240°C for 8 h one week-end, and observing the power consumed. The power consumed was 426 kWh, or the equivalent of 14·6 therms. It might be said that if the heat losses were lower, then possibly later casts than those mentioned could be charged satisfactorily, but there is a danger that the predominant number of suitable casts around 85–100 min, as in Appleby practice, would remain liquid too long and not be suitable for rolling in the time required. Also, casts longer than 100 min tend to have too low a heat content and require some additional heat. The main source of heat loss from the pit is through the covers, and by increasing the amount of insulation in the cover construction, the heat loss could be reduced, but at the present stage it is difficult to say whether there would be any real advantage in lowering it as so much depends on ingots losing heat from the middle rapidly enough to meet the rolling time desired.

The use and quality of coke

It has been found good practice every shift to examine the trough ends by looking through the coke holes over the electrodes. This is done by poking down the coke round the electrode ends and checking to see that the electrodes are covered and not at an excessive temperature. High temperatures are indicative of (*a*) poor contact with the coke, and (*b*) possible air infiltration.

As the pit is drawn, it is also practice to note the level of coke in the trough as bad undulations may result in hot spots. If a hot spot is seen then the trough is rabbled at this point and more coke added if necessary.

After a time, the general level of the coke decreases with the result that, in Appleby practice, a period of about one hour on Wednesday morning and another in non-production time on Saturday night is set aside for replenishing the trough. For a complete week's work this gives 17 cwt of coke consumed, an average of little more than 1 lb/ton of steel heated.

At the beginning of the operation of the pit trouble was experienced in finding a satisfactory grade of coke, and experiments with two types, namely electrode coke and petroleum coke, showed interesting features. The electrode coke received was in about 3-in. lumps which had to be crushed to $\frac{3}{4}$-in. lumps and less. The resultant fines were a small proportion of the whole, so no effort was made to separate them. In a few weeks, using this material in this way, it became evident that overheating was occurring to the detriment of the trough, and consumption of coke was going up.

The petroleum coke was used in two ways. This coke was first received in lumps rather less than $\frac{3}{4}$ in. with a considerable amount of fines. The fines in the first trial, passing through a $\frac{1}{8}$-in. mesh sieve, were discarded. There was no overheating. The next batch of petroleum coke received contained even a greater amount of fines. This batch was used as received and again no over-heating resulted.

Analyses of the various cokes showed varying ash contents. However, indications are that the precise ash content of the coke is not important providing the general level is low. What would appear to be important is the texture of the coke; whether or not it permits intimate contact from piece to piece, ensuring a reasonable conductivity figure. Petroleum coke appears to do this satisfactorily.

TABLE II Electric soaker index for 10-ton ordinary ingots with tap to first ingot charge time of 105–120 min

Pit temperature at start of charging, °C	Tap to first ingot charged, min	Interval: 'first ingot charged' – 'Switch full power on'	Index tap to roll time h	min
1240	105	After 75 min	3	25
	110	„ 50 „	3	30
	115	„ 25 „	3	35
	120	Leave on the whole time	3	40
1220	105	After 50 min	3	25
	110	„ 25 „	3	30
	115	Leave on the whole time	3	35
	120	„	3	40
1200	105	After 25 min	3	25
	110	Leave on the whole time	3	30
	115	„	3	35
	120	„	3	40

Week-end working

During the last shift of the working week, and after the last ingot has been drawn, power is switched off. The soaker is now left as a completely enclosed space, except for the 1-h coking period mentioned earlier. The soaker temperature drops from 1240°C to 1050°C in 24 h, when power is switched on. After 10 h at full power the soaker is back to temperature and ready for charging, the time now being within two hours of the start of the first 10 to 6 shift of the week.

Use of blast-furnace gas

As already mentioned, a small amount of blast-furnace gas can be injected into the soaker to keep the atmosphere reducing. About 40 ft³/h was used all the time, whether ingots were charged or not, for 6 months. The amount of scale produced was negligible, and a gain in yield of about 1% was noted. However, it was later felt desirable to try to minimize the surface defects on the ingot by turning off the gas completely, creating a completely static neutral atmosphere. The gain in yield was still of the order of 1%, as very little scale was produced. As might be expected from this result, little difference was made to the surface defects.

Experiments are now being carried out using a small amount of air, but no definite results are available yet.

One year's working of the electric soaker

Soaker switched on 6 May, 1st charge 13 May 1957

Week no.1, ending 18 May 1957, cumulative throughput 1870 tons

Week no.5, ending 15 June 1957, cumulative throughput 10272 tons

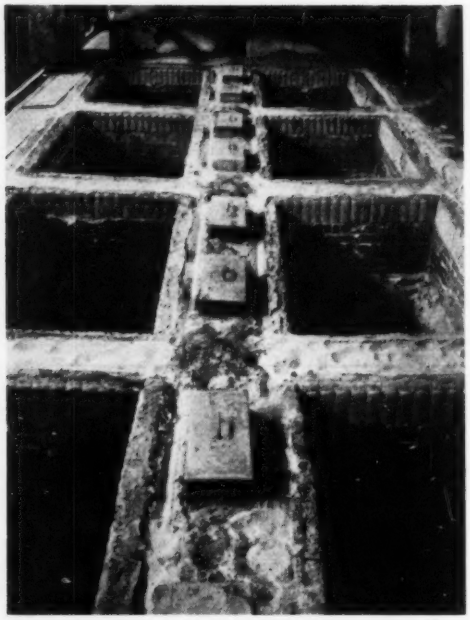
Soaker personnel reported that more coke was being used at one end than the other. Difficulty in keeping the electrode covered, one end far too hot.

Weeks nos.6 and 7, ending 29 June 1957, stop period (Appleby).

Examination of the soaker showed a gap between the end trough section and the surrounding brickwork: the filling had worked out and had allowed the fine coke to trickle down, uncovering the top of the electrode. Filling replaced.

Week no.8, ending 6 July 1957, cumulative throughput 11103 tons

Soaker taken off. Filling out and end trough section collapsed. The brickwork below the end section had subsided, unsuspected in previous trouble. Bases made good at both ends with carborundum blocks.



3 *Top view of the soaker after 1 year's working*

Week no.16, ending 31 August 1957, cumulative throughput 21621 tons
Cooling water supply inadequate. Electrode ends over the past two weeks tending to get hot with full power. Working on intermediate power. Water supply increased by altering the mains. Transformer altered to parallel connections. Proved to be premature, had to revert to series.
Week no.24, ending 26 October 1957, cumulative throughput 36127 tons
On 21 October, one of the electrodes arced and the soaker was switched off. The repair involved changing one electrode, as this had burned into two pieces. The cause was the faulty water supply which had allowed a little of the tin to melt, thus giving air an opportunity to enter the soaker around the electrode.
Week no.27, ending 16 November 1957, cumulative throughput 41924 tons
Trouble experienced with the cast-iron surrounds of each coke hole warping inwards and making additions of coke difficult, but not impossible. Plan to alter at next long shut-down. Working without gas injection.
Week no.37, ending 25 January 1958, cumulative throughput 60804 tons
Hot repair to sealing blocks around nos.4 and 6 cells, a few of the top blocks had moved: repair done in non-production time. No more petroleum coke being used, electrode coke being used in its place.
Week no.38, ending 1 February 1958, cumulative throughput 62534 tons
On 28 January, one electrode arced, again power was quickly taken off. Water was passing satisfactorily and the external appearance of the casing and electrode appeared satisfactory also. The electrode was taken out, but nothing could be found wrong with it. The arcing had apparently taken place a short distance from the end of the electrode. After a good rabbling of the trough, the electrode was put back, and the soaker was put into production again.
Week no.47, ending 5 April 1958, cumulative throughput 77563 tons
Throughout February and March, during the use of electrode coke, there had been periodic arcing in the trough in various places. During week ending 5 April, the soaker was taken off. The coke-hole surrounds were altered by the makers, this time excluding cast iron. The trough was too bad for a further run, in that large cracks had developed along its entire length. The whole trough was taken out and replaced. The bottom of each cell was free from any slag and had hollowed out about 8 in. in the middle, this was filled up by shovelling millscale into it, as a quick repair. The corbelling had worn back about 4 in. but not far enough for a replacement. The linings and arches were in a surface-fused condition and untouched. The covers and hangar bricks suspended therein were as good as new. The electrode coke was replaced with petroleum coke.
Week no.52, ending 10 May 1958, cumulative throughput 86093 tons
Soaker working satisfactorily with none of the previous troubles so far. Averaging 1720 tons per week, with 19 weeks of over 2000 tons.

Throughout the year's working, minor electrical troubles, particularly tap changing, have been experienced, but none has been serious enough to cause a measurable loss in production. Brickwork maintenance has been virtually nil. Trouble with the coke holes and the coke itself should now be avoided. A good water supply should now avoid the danger of melting tin, and air infiltration at this point. It appears that annual replacement of the trough will be necessary, but the failure in March was almost certainly due to the unsatisfactory grade of coke then being used. The trough will have to be cleaned out and the coke replaced, say every six months, at a time most convenient to the rest of the plant. Figure 3 shows a view of the soaking pit after 1 year's working.

CONCLUSIONS

The electric soaker at Appleby-Frodingham has enabled steel to be rolled more cheaply by:

(i) lowering the equivalent therms per ton required to 1·1 which, taking the high cost of electricity, is still less than best current practice at Appleby
(ii) increasing the yield from the ingot by 1%
(iii) lowering the maintenance cost to a fraction of that normally expected on gas-fired soakers.

The soaker has shown that with fast track times and a continuous supply of hot ingots, ingots would be rolled with practically no power consumption at all.

It must be admitted that no scaling can be a disadvantage in not removing surface defects on the ingot, but experience at Appleby-Frodingham, with a single cell, shows that only a marginal scale is necessary to do this, still giving a considerable gain in yield. Further experiments, with small amounts of air in the electric soaker, are being carried out, and it is expected that the surface defects will be removed and the higher yield maintained, confirming the favourable results of the single cell.

ACKNOWLEDGMENTS

The author wishes to thank the Appleby-Frodingham Steel Company for permission to publish this paper. Stein and Atkinson Ltd for permission to use drawings and technical information. Mr A. Jackson, Technical Director of Appleby-Frodingham sponsored the introduction of this unique single-electrode trough furnace for an application not previously used in the UK, and the author wishes to thank him for his encouragement in this work.

NEWS | *Announcements and News of Science and Industry*

THE IRON AND STEEL INSTITUTE

Autumn General Meeting 1959

The Institute's Autumn General Meeting was held in London on Wednesday and Thursday, **2 and 3 December 1959.** The full programme of the meeting was given in the November News section (p.313).

Special Meeting in Italy 1960

The Institute is holding a Special Meeting in Italy from **29 May to 11 June 1960.** The meeting will consist of three sections, the first in northern Italy, with visits to works in Milan, Aosta, Turin, and Genoa, the second in Rome, and the third in Naples. There will be a Joint Meeting with the Associazione Italiana di Metallurgia in Milan during the first week.

An outline of the programme was given in the November News section (p.313); full details will be circulated to members and published in the *Journal* early in 1960.

NEWS OF MEMBERS

Mr **R. Barnaby,** managing director of Brown-Bayley Steels Ltd, has been appointed to the board of the company.

Mr **F. C. Braby,** M.C., has been elected chairman of the council of the British Non-Ferrous Metals Research Association; he will succeed Dr Maurice Cook, C.B.E., on 1 January 1960.

Major **W. R. Brown,** D.S.O., has relinquished the post of joint managing director of the Power-Gas Corporation Ltd, but is continuing as chairman of the board.

Mr **F. B. Cuthbert** is now with the Ford Motor Company Limited, Dagenham.

Mr **P. R. V. Evans** has left Metropolitan-Vickers Electrical Co. Ltd to join the Armour Research Foundation, Chicago.

Mr **L. D. Gloyn-Cox** has graduated from the Royal School of Mines, and is now a technical officer with the Metals Division of Imperial Chemical Industries Ltd.

Mr **J. Hacon** has rejoined the research and development department of the United Steel Companies Ltd as technical control of the creep-testing laboratory.

Dr **R. Hunter** has been elected chairman of the council of the British Steel Castings Research Association.

Mr **C. H. Kain** has retired from the chairmanship of the council of the British Steel Castings Research Association, a post he occupied for over five years.

Dr **S. Klemantaski** has been appointed deputy head of the BISRA Chemistry Department.

Mr **E. H. Rogerson** is retiring from the post of Scottish manager to Cochran and Company, Annan, Ltd on 31 December.

Mr **R. Rolls** has left Taylor Brothers and Co. Ltd to become assistant lecturer in metallurgy at Rotherham College of Technology.

Dr **H. Schenck** has been awarded the Floris Osmond Medal of the Société Française de Métallurgie.

Dr **L. B. Pfeil,** O.B.E., F.R.S., has been awarded the Sainte-Claire Deville Medal of the Société Française de Métallurgie.

Mr **P. J. Scratchley** has resigned from Union Carbide Ltd.

Mr **E. A. Shipley** has left Morris Motors Ltd to join British Ropes Ltd, Doncaster, as head of research–wire division.

Dr **F. T. Sisco** has resigned as director of the Engineering Foundation, New York; he is retaining the post of director of the Foundation's Alloys of Iron Research.

Mr **H. Southern** has been awarded the honorary degree of Master of Technical Science by the University of Sheffield.

Mr **M. D. Tidman** has joined the inspection department of the Dunlop Rim and Wheel Co. Ltd.

Correction

It was incorrectly stated in the September issue of the *Journal* that Dr **T. P. Colclough,** C.B.E. had been awarded an *honorary* degree of D.Met. by the University of Sheffield; the degree was conferred on Dr Colclough after the submission of published work in the usual way.

Obituary

Mr **David Julius Oscar Brandt,** B.SC., A.R.S.M., F.I.M. (*elected* 1946) of Hampton Hill, Middlesex, on 23 November 1959.

Mr **Harold Cecil Burrow** (*elected* 1952), of Menston, on 19 August 1959.

Mr **George Arnold Phillipson,** F.INST.F. (*elected* 1950) of Ebbw Vale, on 18 September 1959.

POWDER METALLURGY JOINT GROUP

Symposium on the powder metallurgy of magnetic materials

The Powder Metallurgy Joint Group held a Symposium on 'The powder metallurgy of magnetic materials' at Church House, Westminster, on **16 December.** Synopses of nine papers presented at this symposium are given below. The complete papers are published in *Powder Metallurgy* no.4.

The coercive force of fine iron powders by E. H. Carman (Imperial College of Science and Technology, London). The intrinsic coercive force of compacts prepared from hydrogen-reduced ferric oxide powder has been studied as a function of particle size in the range 200–800 Å. For well dispersed powder the coercive force increases sharply with particle size to a value of 970 Oe, where the nominal particle size is 260 Å; above this value the coercive force decreases sharply. An electron-microscope study of powders in the neighbourhood of the maximum shows that the experimentally determined coercive force is in good agreement with recent theory. X-ray line-broadening experiments indicate that packing effects, rather than strain anisotropy within particles, control the coercive force of compacts. A linear variation with packing density is obtained for all particle sizes investigated.

The development of 50:50 *nickel–iron for magnetic-amplifier cores* by G. P. J. Buchi, T. B. Burnett, and J. E. Thompson (Research Laboratories of the English Electric Co. Ltd, Stafford) A 50 wt-% nickel–iron strip 0·004 in. thick has been produced from commercially pure material by powder-metallurgy techniques. The degree of cold rolling and the annealing temperature were varied over a limited range. The suitability of the material for magnetic-amplifier application has been tested by a method described.

Annealing twins, formed during the annealing process, have a deleterious effect on the dc coercive force, the ac loss, and the magnetic-amplifier characteristics. The density of these twins can be made zero by suitable heat-treatment; for a given degree of cold rolling there is an appropriate annealing temperature to give this result. Experimental results are quoted to show that optimum magnetic properties are achieved in twin-free strip.

The production of silicon–iron magnetic strip with the (110) [001] *texture, by cold rolling from sintered compacts* by E. V. Walker and (Miss) J. Howard (Post Office Research Station, London). It is shown that secondary recrystallization and development of the (110) [001] texture in 3¼% silicon–iron strip can be obtained by control of the oxygen content of the hydrogen sintering atmosphere. The conditions required are described.

The sintered compact is then cold rolled according to a schedule used for rolling grain-oriented silicon–iron from a cast ingot.

It is found that the temperature of secondary recrystallization is higher than that for conventionally made strip.

It is suggested that a critical amount of silicon is oxidized to silica during sintering and that this silica acts as a dispersed phase in the inhibition-dependent mechanism known to be responsible for secondary recrystallization.

In an appendix by D. C. Shotton an account is given of a short X-ray method for checking the texture of the silicon–iron strip.

The production of grain-oriented 50:50 *nickel–iron magnetic strip by cold rolling from sintered compacts* by E. V. Walker and R. E. S. Walters (Post Office Research Station, London). 50:50 nickel–iron strip was cold rolled from sintered compacts to thicknesses of 0·0015 and 0·004 in., with final reductions of 92–99%. After annealing at 1050–1200°C, the cube texture developed, thus giving a material with a rectangular hysteresis loop when magnetized in either the rolling or the transverse-direction.

The alloys with the best magnetic properties contained 48–50% nickel. In this range of composition the remanence ratio and coercivity varied from 0·91 to 0·94 and 0·11 to 0·19 respectively, depending upon the processing schedule used.

With the recommended processing schedule, values for the remanence ratio and coercivity of 0·92–0·94 and 0·11–0·13, respectively, were obtained.

Unlike the texture of strip rolled from a conventionally cast ingot, the development of cube texture in strip rolled from a sintered compact is not critically dependent on the temperature of the final anneal.

The fabrication of soft magnetic alloy strip from powders by H. H. Scholefield and S. G. G. Richardson (Telegraph Construction and Maintenance Co. Ltd, Crawley). An investigation has been carried out into the properties of high-permeability nickel–iron-base alloys made by powder-metallurgical methods. It is shown that at the upper limits of composition considered the initial permeability of Mumetal is still increasing. With the straight nickel–iron alloys maximum permeability decreases over the range 45–55% nickel, but the initial permeability tends to increase gradually over the upper end of this range. It is shown that the results are reproducible. Mention is also made of sintered silicon–irons and cobalt–irons.

Permanent magnets from elongated single-domain particles by F. E. Luborsky, T. O. Paine, and L. I. Mendelsohn (General Electric Company, USA). A process is described for producing elongated single-domain (ESD) fine-particle magnets. The 150-Å ESD iron or iron–cobalt alloy particles are prepared by

controlled electrodeposition into mercury, followed by thermal growth and treatment with a third metal to attain optimum particle shape and magnetic properties. The particles are then aligned by a magnetic field, compacted under pressure, freed of mercury by vacuum distillation, and embedded in a suitable matrix. This is ground to a coarse powder and fed into automatic presses for realigning and compacting to the final magnet shape. The factors controlling each step of the process are discussed, and the advantages of magnets with artificial microstructures synthesized by this approach are pointed out. The process described produces commercial ESD iron and iron–cobalt magnets with energy products of 2·2 and 3·5 million gauss-oersteds, and laboratory ESD iron and iron–cobalt magnets of 4·2 and 5·0 million gauss-oersteds.

The variation in intrinsic coercivity of iron–cobalt powders prepared by electrolysis into mercury by W. Wright (Permanent Magnet Association, Sheffield). Iron, cobalt, and iron–cobalt alloy particles in mercury have been prepared by electrolysis over a mercury cathode. The intrinsic coercivity at −70°C of these particles has been measured, as deposited and after various heat-treatments; a marked difference in properties is found, which is dependent not only on heat-treatment, but also on whether or not the cathode was stirred during electrolysis. The effect of further metal additions to the iron–cobalt–mercury system is noted. In the discussion an attempt is made to explain the differences observed.

The effect of grain size on saturation magnetization of barium ferrite powders by K. Torkar and O. Fredriksen (Technische Hochschule, Graz). Studies on barium ferrite powder showed a decrease in saturation magnetization with decreasing grain size. This phenomenon had previously been observed in iron and magnetite powders and was attributed to the existence of a disturbed layer on the individual powder grains (Hüttig's surface layer). This layer may vary in thickness according to the manufacturing process used, and the degree of disturbance will increase with the fineness of the powders.

A study of the magnetic properties of sintered ferrites, using single-crystal data by F. W. Harrison, K. Hoselitz, and J. E. Knowles (Mullard Research Laboratories, Salfords, nr. Redhill). An indication of the dependence of the magnetic properties of polycrystalline sintered ferrites on the conditions of preparation is given.

In the design and understanding of the properties of these materials it is valuable, and sometimes essential, to make use of data obtained from measurements on single crystals. Methods of preparation of ferrite single crystals, namely the Verneuil or flame-fusion method, the Bridgman–Stockbarger method, and the lead oxide flux method, are briefly described.

To illustrate the way in which measurements on polycrystalline and single-crystal specimens complement each other in the understanding of the magnetic behaviour of ferrites, an investigation of the properties of a ferrite with a so-called 'square' hysteresis loop is discussed.

Powder Metallurgy no.4

In addition to the nine symposium papers given above, *Powder Metallurgy* no.4 contains two further papers and two reports of discussions:

The powder metallurgy of titanium–tin alloys containing up to 15% tin by R. F. Smart and Professor E. C. Ellwood (Tin Research Institute, Greenford). Density measurements and data on the mechanical properties of titanium–tin alloys, fabricated by powder metallurgy from sodium-reduced titanium, are reported.

Low porosities were achieved after a single pressing and sintering operation. A typical set of preparation conditions involved compacting at 40 tons/in² and sintering, in vacuum, at 1300°C for 1 h. With tin contents above 5%, evaporation of tin during sintering could prove troublesome.

The presence of tin strengthened titanium markedly. The addition of 15% tin increased the ultimate tensile stress at room temperature by ~90%, with a corresponding, though less marked, reduction in ductility.

Observations on the sintering of SAP by E. M. Modl-Onitich (Research Laboratories of Aluminium Industrie AG., Neuhausen)

Discussion on 'Theoretical aspects of sintering' A summary of the discussion held on 29 April 1959.

Discussion on 'The powder metallurgy of metal–ceramic materials' A summary of the discussion held on 17 December 1958.

Powder Metallurgy, which appears twice a year, is the official organ of the Powder Metallurgy Joint Group. It is obtainable by annual subscription at 25*s* (post free) to non-members, with a privileged rate of subscription to members of The Iron and Steel Institute and The Institute of Metals.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

53rd Steelmaking Conference: Continuous casting

The subject of continuous casting of steel is well to the fore in the British steel industry. The full force of this statement can perhaps only be appreciated by those who attended the 53rd Steelmaking Conference held on 30 September and 1 October, at Southport.

The Conference opened with a report of the visit of the UK delegation to Russia, in April this year, to study and see continuous casting of steel there, and discuss the technical aspects of its future development. Dr W. S. Walker, leader of the team, introduced the report, and the *Theoretical considerations of plant design* and *Practical considerations of plant design* were described by Mr G. Fenton and Mr H. Scriven respectively. To conclude the presentation of the Russian work in this field, the film 'Continuous Casting in Russia' was shown.

The next speaker, M J. Zaeytydt (CNRM) described *The continuous casting of basic Bessemer steel at Charleroi, Belgium*, and showed a very fine film of the entire journey of a heat of basic Bessemer rimming steel from the time it left the converter until it was in the form of an 8-in. square continuously cast ingot.

On the second day, the work on continuous casting in the UK was considered. The conference resumed with a paper by Mr G. Littlewood (BISRA) on the *Continuous casting at BISRA laboratories: present programme of research*. A film of the continuous casting plant at Barrow in commercial operation for the production of 2-in. dia. billets was then shown, and this was followed by a report by Mr I. M. D. Halliday (Barrow Steel Works Ltd) on *Recent development in continuous casting at Barrow*. At this plant, the casting of slabs, so far up to 36 in. wide and 5½ in. thick and 9 in. square sections in killed and rimming grades of steel has been achieved.

The final paper of the conference was presented by Mr J. Savage (Continuous Casting Co. Ltd) under the title *The world outlook on continuous casting of steel*. Mr Savage reviewed critically the changing attitude towards continuous casting of steel since it was first put forward about one hundred years ago by Sir Henry Bessemer. He emphasized that the papers considered at the conference had demonstrated the firm faith that both the design engineer and the practical steelmaker now had in the future of the process.

CONTRIBUTORS TO THE JOURNAL

J. M. Slater British Steel Castings Research Association (*author of paper in November issue*). Mr Slater was born in Sheffield in 1929 and educated at High Storrs Grammar School, Sheffield. He joined the staff of the Safety in Mines Research Board in 1946, where he worked on problems of dust research and the control of mine dusts. After National Service from 1947 to 1949, he returned to the Safety in Mines Research Establishment until 1951, when he joined the research and development division of the British Steel Founders' Association, now the British Steel Castings Research Association. He has recently completed a survey of atmospheric dusts in the dressing shops of over 60 foundries, and is at present engaged on the testing of dust collectors. He became an Associate Member of the Institution of Plant Engineers earlier this year.

J. M. Slater

P. J. Sukolski

P. J. Sukolski, B.E.HONS. – Senior Metallurgist, McKechne Bros. Ltd (*author of paper in November issue*).

Peter Sukolski was born in 1930. From 1948 to 1952 he attended Victoria and Canterbury University Colleges, New Zealand, and graduated with the degree of B.E.Hons. with first-class honours for postgraduate work on the mechanics of metal cutting. After almost a year as a tool design engineer at General Motors (N.Z.) Ltd, he came to England in 1954 and joined the Mechanical Working Division of BISRA. During 1956 he worked for six months at Jernkontoret, Stockholm, concerning himself mainly with problems of hot working of steel. Subsequently he returned to BISRA and, until he took up his present position in 1958, he was a Senior Scientific Officer, being responsible for work on steel extrusion.

EDUCATION

Welding technology

The courses offered by The Institute of Welding's School of Welding Technology for early 1960 include practical ultrasonic inspection, resistance welding, welding of atomic energy plant, welding for junior management, inert-gas arc welding, and welded design and construction in corrosion- and heat-resisting materials.

Full details of these and later courses may be obtained from the Secretary, The Institute of Welding, 54 Prince's Gate, Exhibition Road, London SW7.

Mond Nickel Fellowships

The Mond Nickel Fellowships Committee recently announced the award of Fellowships for 1959 to the following applicants:

D. J. O. MANN (John Lysaght's Scunthorpe Works Ltd) to study the practical applications of recent metallurgical research techniques to the production of basic semi-finished steel

N. J. B. POCOCK (Capper Pass and Son Ltd) to study developments in extraction metallurgy in the UK, Europe, the USA, and Canada, and their dependence on the size and location of the organizations concerned.

FORTHCOMING CONFERENCES AND EXHIBITIONS

Mineral processing

The 1960 International Mineral Processing Congress is to be held in London in April 1960. Arrangements are in the hands of the Institution of Mining and Metallurgy, to whom all enquiries should be addressed.

In conjunction with the Congress there will be a Mineral Processing Exhibition, sponsored by the British Chemical Plant Manufacturers' Association and organized by Industrial Exhibitions (Services) Ltd. The exhibition will be held in the two halls flanking the main assembly hall at Church House, Westminster, in which the Congress sessions will be held.

7th Commonwealth Mining and Metallurgical Congress

Arrangements are being made for the 7th Commonwealth Mining and Metallurgical Congress, which is to be held in Southern Africa in April and May 1961. Further information may be obtained from the Congress Manager at 5 Hollard Street, PO Box 809, Johannesburg, South Africa.

NEWS OF SCIENCE AND INDUSTRY

Board changes at SCW

The Steel Company of Wales Ltd has announced that, following the completion of the company's third development plan, and in view of the impending retirement of Captain H. Leighton Davies, C.B.E., in June 1960, the following appointments have been made to the board of directors:

Mr R. W. Evans
The Hon. R. H. M. Kindersley
Mr I. S. Scott-Maxwell

Captain Leighton Davies, who was President of The Iron and Steel Institute in 1952–1953, will continue to serve the company as a consultant after his retirement.

Mr Scott-Maxwell is appointed general manager designate to the tinplate division, to succeed Captain Leighton Davies on his retirement. Mr J. Shirley Gazard, at present assistant general manager of the tinplate division, will become deputy general manager at that time.

Mr Evans, at present assistant general manager (operations) of the steel division, is appointed deputy general manager of that division. Mr Kindersley joins the board as a non-executive director.

A member of the Institute since 1936, Mr Scott-Maxwell was with Colvilles Ltd and the BISF before joining the Steel Company of Wales Ltd in 1952 as chief engineer of the steel division. Mr Evans has been a Member since 1928; he was awarded a Williams Prize in 1944, and was elected an Honorary Member of Council in 1958.

R. W. Evans

I. S. Scott-Maxwell

Vacuum science and technology

Following The Institute of Physics' conference in April 1959 on high vacua, various suggestions were made for arranging regular British meetings on vacuum science and technology, and for British participation in international conferences in this field.

As a result of informal discussions between societies and institutes in this country, a Joint British Committee for Vacuum Science and Technology has now been formed. The committee consists of representatives from each of the following bodies: The Institute of Biology, The Institution of Chemical Engineers, The Royal Institute of Chemistry, The Institution of Electrical Engineers, The Iron and Steel Institute, The Institution of Mechanical Engineers, The Institute of Metals, The Institute of Petroleum, The Physical Society, and The Institute of Physics.

Its objects are (*a*) to co-ordinate and help to initiate meetings in the whole field of vacuum science and technology arranged by constituent bodies, and (*b*) to act in the collective interest of the constituent bodies by maintaining liaison with the International Organization for Vacuum Science and Technology and with national vacuum societies.

The Institute of Physics has agreed to provide the secretariat for the joint committee; communications should be addressed to the Secretary of the Joint British Committee at its headquarters, 47 Belgrave Square, London SW1.

Honour for INA

Her Majesty the Queen has graciously approved of the Institution of Naval Architects being known in future as the Royal Institution of Naval Architects. The use of the title has taken effect immediately.

Wellman–VÖEST contract for LD

A contract was signed on 12 November between VÖEST AG and The Wellman Smith Owen Engineering Corporation Ltd in Linz by Herr Hitzinger and Sir Peter Roberts, BT, for the exclusive co-operation between these two companies in the UK for the design, supply, and erection of plant and equipment for the LD steelmaking process.

Brymbo development plans

Brymbo Steel Works, the North Wales special and alloy steel plant, announce that the board of their parent company, Guest Keen and Nettlefolds Ltd has approved a second development scheme involving capital expenditure of over £2 million.

This second scheme follows on the first, which began in 1956 and was completed this year, in the course of which the old open-hearth melting shop was replaced by a new melting shop with three 45-ton electric arc furnaces, supplementing the existing three 30-ton furnaces and making the plant all-electric. At the same time the Brymbo process, based on the pre-refining of blast-furnace metal with tonnage oxygen for subsequent use in electric furnaces, came into operation.

The new development scheme follows on logically from the modernizing of the steelmaking plant. It consists of the complete replacement of the four old ingot-reheating furnaces by a continuous bogie furnace, and the installation of a new cogging mill, which will enable the works to take full advantage of the increased steelmaking facilities and will roll ingots 2½–3 times as large as those at present being rolled. At the same time bottom-pouring facilities will be introduced, and the handling and cooling arrangements for the finished billets will be completely revised.

As a result of these changes, the throughput of ingots will be increased, as soon as the mill comes into operation. Ample steelmaking facilities to enable this increase to take place are already available.

The development scheme will be in two stages. The new reheating furnace and the bottom-pouring facilities should be in full operation by August 1960 and the new cogging mill and billet handling facilities will be brought into operation in August 1961.

Hydraulic equipment association

British hydraulic equipment manufacturers have now formed their own association, The Association of Hydraulic Equipment Manufacturers, with offices at 38/40 Eccleston Square, London SW1.

The many manufacturers engaged in this fast developing industry have found the need for a central national organization to look after the interests of the industry as a whole, to collect and to distribute technical information, to advise on exhibitions for the industry at home and abroad, and to encourage and sponsor research for the benefit of the members.

English–French foundry vocabulary

The information department of the British Cast Iron Research Association has recently published a 28-page pocket-size glossary of English and French foundry and metallurgical terms. This very valuable little book is surprisingly comprehensive; copies may be obtained from BCIRA, Bordesley Hall, Alvechurch, Birmingham, price 7*s* 6*d* per copy.

Contract news

An additional sintering plant is to be supplied by *Head Wrightson Iron and Steel Works Engineering Ltd* to the Avilés works of Empresa Nacional Siderurgica SA, the Spanish national steel company in northern Spain. The new plant will form an addition to the existing sinter plant, and is designed to produce an additional 10000 tons of blast-furnace sinter per week. The total value of the equipment to be supplied is £500000. Head Wrightson have been intimately connected with the building of the Avilés works, which is one of the most modern integrated plants in Europe; the company was responsible for the design and construction of the ironmaking plant, covering ore preparation installations and blast-furnace plant.

Another subsidiary of Head Wrightson Ltd, the *Head Wrightson Machine Co. Ltd*, has been awarded contracts valued at over £2 million for the installation of an electrolytic tinning line at the Ebbw Vale works of Richard Thomas and Baldwins Ltd. The new line, which will be delivered in eighteen months, will be capable of tinning and recoiling at 1500 ft/min.

Birlec Ltd have announced four contracts for furnaces. A pit-type annealing furnace for the heat-treatment of alloy-steel forgings up to 100 tons in weight for the English Steel Corporation Ltd will be among the largest heat-treatment furnaces in the UK, and will incorporate many special design features, including a control system for securing very close temperature tolerances. Two cylindrical furnaces for annealing reactor fuel elements have been ordered by the UK Atomic Energy Authority. A very high vacuum (10^{-4} in. Hg) will be maintained in the heating chamber to protect the charge. A third electric annealing furnace has been ordered by Oy Vuoksenniska AB of Finland. This will be of the lift-off bell type, and is designed for annealing steel bars of up to 6 m long.

The fourth furnace, ordered from *Birlec-Efco (Melting) Ltd*, is a 21-ft dia. arc melting furnace, with a nominal charge capacity of 80 tons, making it the largest in the UK. It has been ordered by the English Steel Corporation Ltd, and will be used in connection with a scheme for the vacuum-casting of ingots for forging. High-grade carbon, alloy, and stainless steels will be melted and refined in the furnace and poured via an open ladle into a vacuum ladle.

The latest contract announced for the Ravenscraig plant of Colvilles Ltd is for the supply and construction of a blast-furnace gas-cleaning plant; the suppliers will be *Head Wrightson Iron and Steel Works Engineering Ltd*. The complete plant will be capable of cleaning 15 million ft³ of gas per hour; it will comprise one gas washing tower, two wet-tube electrostatic precipitators, and ancillary equipment. It is expected to be in commission by mid-1961.

Powder dispenser

A powder dispenser that enables fluxes, alloying elements, and structure-controlling additions to be introduced below the surface of molten metals has been developed by British Oxygen Research and Development Ltd, and is now being marketed by British Oxygen Gases Ltd.

The dispenser has been robustly designed for service in foundries and melting shops; it has a capacity of 150 lb of calcium carbide or 100 lb of graphite. These powders can be dispensed at up to 30 lb/min, using a stream of nitrogen and an electro-graphite lance. So far, trials have been carried out chiefly with these materials in iron foundries, but there are indications that the method will have a much wider field of application, for example, in the introduction of lime and ferroalloys into electric furnaces.

INDUSTRIAL PUBLICATIONS RECEIVED

Information Sheet M.897/1 from Jessop-Saville Ltd deals with forging alloys for high-temperature applications.

Lodge-Cottrell Ltd have recently issued brochures on electrofilters for blast-furnace and special applications.

Delapena and Son Ltd have begun to issue a news sheet known as *Delapena Developments*, dealing with induction heating; it is hoped to publish this monthly after the first three issues, which are bi-monthly.

Five new single-sheet leaflets (IN.1, IN.3–6) from The Incandescent Heat Co. Ltd give details of Incanite, a special process cast iron.

From Jones and Shipman Ltd comes catalogue 237H, which describes the Model 1400 precision toolroom surface grinder.

Fry's Diecastings Ltd have produced a 32-page technical handbook on *Designing for Diecasting*.

A 26-page illustrated booklet on rotary driers has been issued by Head Wrightson Stockton Forge Ltd.

Publication 758 from Crofts (Engineers) Ltd is devoted to their radiation combined spur and worm double reduction gear units.

CHANGES OF ADDRESS AND TITLE

The offices and factory of Colloidal Graphite Ltd have been transferred to Sheaf Island Works, Pond Hill, Sheffield 1 (telephone 27397).

The name of the Synthetic Carbon and Engineering Co. Ltd has been changed to Morgan Components Ltd, in order to clarify the association with the parent company, The Morgan Crucible Co. Ltd.

CORRIGENDA

The following errors have been pointed out in the paper by H. R. Schubert on *Nitrogen in early steelmaking* (*JISI*, 1959, Aug., **192**, 383):

Left-hand column, line 9: '100 B.C.' should be '1000 B.C.'

Right-hand column, line 5: 'temporary' should be 'tempering'.

DIARY

1–5 Dec.—INDIAN INSTITUTE OF METALS—13th Annual Technical Meeting—Bangalore.

1 Dec.—SHEFFIELD METALLURGICAL ASSOCIATION—*Clean steel*, by K. C. Barraclough—BISRA, Hoyle Street, Sheffield, 7 pm.

2–3 Dec.—THE IRON AND STEEL INSTITUTE—Autumn General Meeting—London.

2 Dec. SWANSEA AND DISTRICT METALLURGICAL SOCIETY—*Alternatives to the blast-furnace*, by J. M. Ridgion—Central Library Swansea, 6.45 pm.

3 Dec.—EBBW VALE METALLURGICAL SOCIETY—*Special cast irons*, by H. Morrogh—RTB Lecture Rooms, 7.15 pm.

3 Dec.—LIVERPOOL METALLURGICAL SOCIETY—*Basic aspects of metal fatigue*, by Dr T. Broom—Department of Metallurgy, Liverpool University, 7 pm.

4 Dec.—SHEFFIELD METALLURGICAL ASSOCIATION—Annual Dinner-dance—Royal Victoria Hotel, Sheffield.

7 Dec.—CLEVELAND INSTITUTION OF ENGINEERS—*Manufacture of small steel castings by new moulding techniques*—Cleveland Scientific and Technical Institution, Middlesbrough, 6.30 pm.

8 Dec.—SHEFFIELD METALLURGICAL ASSOCIATION (Refractories Group)—*Gemstones*, by T. Jones–BISRA, Hoyle Street, Sheffield, 7.30 pm.

9 Dec.—MANCHESTER METALLURGICAL SOCIETY—*Guided missiles: metallurgical problems as seen by the designer*, by J. L. Crowder—Central Library, Manchester, 6.30 pm.

9 Dec.—NORTH WALES METALLURGICAL SOCIETY—*Deep drawing*, by D. H. Lloyd—Flintshire Technical College, Connah's Quay, 7 pm.

10 Dec.—STAFFORDSHIRE IRON AND STEEL INSTITUTE—Film evening—Station Hotel, Dudley, 7.30 pm.

14 Dec.—LINCOLNSHIRE IRON AND STEEL INSTITUTE—*Atmospheric pollution*, by S. H. Brooks—North Lindsey Technical College, Scunthorpe, 7.30 pm.

15 Dec.—BRITISH NUCLEAR ENERGY CONFERENCE—*The shielding and security of marine reactors*, by K. Maddocks—Institute of Marine Engineers, 76 Mark Lane, London EC3, 5.30 pm.

15 Dec.—NEWPORT AND DISTRICT METALLURGICAL SOCIETY—*The basic open-hearth, present and future*, by R. W. Evans—Whitehead Institute, Newport, 7 pm.

15 Dec.—SHEFFIELD METALLURGICAL ASSOCIATION—*Developments in heavy plate steels*, by W. Barr, O.B.E.—BISRA, Hoyle Street, Sheffield, 7 pm.

16 Dec.—POWDER METALLURGY JOINT GROUP—Symposium on *The powder metallurgy of magnetic materials*—Church House, London SW1.

Dec.—WEST OF SCOTLAND IRON AND STEEL INSTITUTE—*Self-fluxing sinter*, by E. H. Baldwin, I. M. Mathieson, and D. McNeil—39 Elmbank Crescent, Glasgow, 6.45 pm.

1 Jan.—CLEVELAND INSTITUTION OF ENGINEERS—*Iron ore from Cerro Bolivar* (film)—Cleveland Scientific and Technical Institution, Middlesbrough, 6.30 pm.

5 Jan.—SHEFFIELD METALLURGICAL ASSOCIATION (Methods of Analysis Group)—Annual General Meeting and Presidential Address—BISRA, Hoyle Street, Sheffield, 7 pm.

6 Jan.—SWANSEA AND DISTRICT METALLURGICAL SOCIETY—*Steel for atomic energy*, by B. Watkins—Central Library, Swansea, 6.45 pm.

7 Jan.—NEWPORT AND DISTRICT METALLURGICAL SOCIETY—*Automatic control in rolling mills*, by P. Briggs—Whitehead Institute, Newport, 7 pm.

12 Jan.—SHEFFIELD METALLURGICAL ASSOCIATION (Refractories Group)—Annual General Meeting and Presidential Address—BISRA, Hoyle Street, Sheffield, 7.30 pm.

13 Jan.—MANCHESTER METALLURGICAL SOCIETY—*The newer methods of steelmaking*, by J. Pearson—Central Library, Manchester, 6.30 pm.

13 Jan.—NORTH WALES METALLURGICAL SOCIETY—*Analytical control by means of the Quantometer and Quantovac*, by W. S. Sykes—Flintshire Technical College, Connah's Quay, 7 pm.

13 Jan.—SOCIETY OF CHEMICAL INDUSTRY (Corrosion Group)—*Corrosion problems of high-temperature pressurized water reactors*, by J. N. Wanklyn—14 Belgrave Square, London SW1, 6 pm.

14 Jan.—STAFFORDSHIRE IRON AND STEEL INSTITUTE—*Materials used and methods of construction involved in the industrial use of atomic energy*, by L. Grainger—Station Hotel, Dudley, 7.30 pm.

BRITISH IRON AND STEEL INDUSTRY TRANSLATION SERVICE

The following translations are now available, in addition to those given on page 316 of the November 1959 issue of the *Journal*:

945 'Manufacture of steel in the arc furnace.' COLIN, J. *L'Aciérie Electrique*, 1957, (Cahiers du Cessid), (2), Pt.4, pp. 1–80. (£14)

1231 'Rolls for cold rolling. MELON, P. *Rev. Univ. Mines*, 1945, Sept. 15, pp. 128–137. (£5 5*s* 0*d*)

1272 'Stability of position of equilibrium of a journal on an oil film.' KOROVCHINSKII, M. V. *USSR Akad. Nauk*. Symposium: 'Friction and wear in machines' 1956, pp. 264–323. (£8)

1278 'The effects of individual and complex deoxidizing additives on a manganese, silicon and aluminium basis on the quantity and arrangement of non-metallic inclusions in steel.' MYSLIVEC, T. *Hutnické Listy*, 1957, (11), pp. 989–1000. (£7 10*s* 0*d*)

1331 'Some experimental investigations regarding wire-drawing.' HOFSTEN, C. O. VON, and E. LINDSTRAND. *Jernkontorets Ann.*, 1958, (3), pp. 128–164. (£8 10*s* 0*d*)

1332 'The decomposition of wüstite in the presence of metallic iron after quenching to temperatures below 570°C.' FISCHER, W. A., and A. HOFFMANN. *Arch. Eisenhüt.*, 1958, Feb., pp. 107–113. (£5 6*s* 0*d*)

1333 'The decomposition of wüstite at temperatures below 570°C in the presence of iron.' FISCHER, W. A., *et al. Arch. Eisenhütt.*, 1956, Aug., pp. 521–529. (£8 10*s* 0*d*)

1378 'Ultrasonic testing of cast irons with laminar and spheroidal graphite formation.' PATTERSON, W., and E. BODMER. *Giesserei*, 1957, July, pp. 909–917. (£4 15*s* 0*d*)

1386 'Measuring the wear of blast-furnace linings by means of radio-active isotopes.' SCHEPERS, A., and F.-R. LICHT. *Stahl u. Eisen*, 1959, May 14, pp. 669–674. (£4 5*s* 0*d*)

1395 'Oxygen in open-hearth furnaces. Data from reports and practice. I. Modern processes.' FÜSSL, E. *Radex Rund.*, 1959, May, pp. 533–545. (£6)

1399 'The primary crystallization of steel undercooling ability and nucleus formation in the liquid condition.' BARDENHEUER, P., and R. BLECKMANN. *Mitt. Kaiser-Wilhelm Inst.*, 1939, (13), 201–212. (£7 10*s* 0*d*)

1401 'The formation of Goss texture in iron-silicon alloys.' DETERT, K. *Metall*, 1958, Sept., pp. 817–821. (£4 10*s* 0*d*)

1402 'Construction and operation of a static frequency trebler for heating and melting metal.' SEULEN, G. W. *Z. Metallk.*, 1959, May, pp. 299–306. (£4)

1403 'Study of the segregation of arsenic and copper by means of autoradiography and quantitative examination with the Castaing microprobe.' CRUSSARD, C., *et al. Rev. Mét.*, 1959, Apr., pp. 395–406. (£4 15*s* 0*d*)

1424 'Oxygen in blast furnace smelting.' SHAPOVALOV, M. A. *Kislorod*, 1958, (4), pp. 1–11. (£6 5*s* 0*d*)

1426 'Relations between embrittlement temperatures obtained with a wide variety of differently shaped impact specimens manufactured from structural steels.' (With discussion) KUSSMAN, H. *Stahl u. Eisen*, 1959, July 23, 1065–1075. (£7 5*s* 0*d*)

1428 'Combustion with simultaneous heat transfer. I. Mathematical deductions.' JESCHAR, R. *Arch. Eisenhüt.*, 1959, June, pp. 329–335. (£4 15*s* 0*d*)

1429 'Combustion with simultaneous heat transfer. II. Comparison of theory and experiment.' HANSEN, M., and R. JESCHAR. *Arch. Eisenhüt.*, 1959, July, pp. 397–405. (£6 10*s* 0*d*)

1446 'Possibilities of saving steel in the use of sections.' RYTEL, K. *Neue Hütte*, 1959, (6), pp. 343–351. (£4 5*s* 0*d*)

1447 'Determination of the quenching capacity of quenching oils. II. The value and suitability of various test procedures' SCHAABER, O., and R. CHATTERJEE-FISCHER. *Industrieblatt* (Stuttgart), 1959, July, pp. 321–324. (£3 15*s* 0*d*)

1448 'Electron microscope investigation of the structure of metal corrosion layers and adhesive deposits.' PFEFFERKORN, G. *VGB, Mitt.*, 1958, Dec., pp. 375–381. (£5 5*s* 0*d*)

1450 'The treatment of spent pickling solutions and waste waters in the iron and steel industry using ion exchange membranes.' QUITMANN, H. *Draht*, 1959, May, pp. 225–229. (£4 5*s* 0*d*)

1451 'Relations between brittleness at high and low temperatures in 18–8 type austenitic steels.' GUEUSSIER, A., and R. CASTRO. *Rev. Mét.*, 1958, (2), pp. 107–122. (£8 15*s* 0*d*)

1457 'The use of the tungsten electrode in the potentiometric determination of manganese in steel.' SUAREZ ACOSTA, R. *Inst. Hierro Acero*, 1958, July–Sept., pp. 177–179. (£1 15*s* 0*d*)

1459 'Method of evaluation and sources of error in quantitative photoelectric spectral analysis.' DIEBEL, H. *Arch. Eisenhütt.*, 1958, (5), pp. 275–281. (£5 5*s* 0*d*)

1466 'Production of tubes with internal plastic coating.' GRINBERG, S. A. *Stal'*, 1958, Nov., pp. 1018–1020. (£3)

ABSTRACTS OF CURRENT LITERATURE *Iron and Steel Manufacture and Related Subjects* AND BOOK NOTICES

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*Abstracts, the reference to which is marked with an asterisk are, or are to be made available as translations.

MINERAL RESOURCES

The Pyrenean deposits of iron ore A.Guedras (*Mét. Constr. Méc.*, 1959, **91,** Apr., 299, 301, 303) The location, composition and beneficiation of these deposits are described, and an outline is given of the blast furnace and low-shaft furnace reduction processes used in South-Eastern France, with some reference to the possibilities of direct reduction using the Lacq natural gas deposits.

Discoveries of some important Swedish ore deposits G. T. Lindroth (*Blad Bergs. Vänner*, 1958, **33,** (3), 129–187) An historical survey is given of the discovery of some of Sweden's principal iron ore deposits from the eighteenth century onwards; the important part played by the Swedish mining compass and the Tiberg 'magnetic inclinator' in locating magnetic anomalies is stressed (22 refs.).

The Wabana ore mine in Newfoundland H. Apfelbeck (*Berg. Hütten. Monatsh.*, 1959, **104,** Mar., 57–62) The geology, mining techniques and beneficiation of the Wabana deposits are described.

Modern mining in Sweden I. Janelid (*Berg. Hütten. Monatsh.*, 1359, **104,** Mar. 62–67), An outline is given of modern Swedish mining; location of the principal deposits (mainly iron ore), and the mining techniques used are indicated, with some reference to grading and beneficiation.

Classification of Brazilian raw materials O. H. Leonardos (*Eng. Min. e Met.*, 1958, **28,** Aug., 111–112; Sept., 161–164) [In Portuguese] The industrially useful raw materials of Brazil are listed under six headings: ores, industrial minerals, building materials, fuels, gems, and mineral waters and, for each, a complete list of mines with their locations, owners, and outputs is given.—P.S.

ORES—MINING AND TREATMENT

Discharge and handling of ores in American ports Guitonneau (*Echo Mines*, 1959, Apr., 213–217) A report, mainly on the Great Lakes, presented after a visit.

Progress in safety measures in the iron ore mines of Eastern France (*Ann. Mines*, 1959, Mar., 161–172) An account, illustrated by statistics is given of progress in safety measures and education in these mines.

Transport of liquid oxygen in the iron ore mines of the Lorraine Basin C. Tréguer (*Ann. Mines*, 1959, Mar., 173–176) Details are given of the trucks designed for the transport of the liquid O_2 used as an explosive in the Lorraine mines.

The 'Bunker on Wheels': an essay on ore transport by the railway from the ship to the blast furnace G. Dilli (*Stahl Eisen*, 1959, **79,** July 23, 1041–1057) If the smelters are not situated at a harbour, then the storage of imported iron ore is best done in 'bunkers on wheels', i.e. in trucks, and in stock yards near the blast furnace. The treatment is statistical and economic.—T.G.

Blending iron ores at metallurgical works Kh. P. Zaitsev, I. A. Volokh and Z. N. Vorogushina (*Stal'*, 1959, (5), 385–389) A survey of the Ukraine has been made disclosing large day-to-day variations in the ore deliveries with consequent difficulties in maintaining uniform blends. Blending in the stockyards where sufficient supplies existed gave greater uniformity of working of sinter plants and furnaces.

The development of iron ore enrichment in Germany M. Pasquet (*Ann. Mines*, 1959, Feb., 79–102) The history of the development of iron ore enrichment in Germany is followed by a detailed description of the ore concentration plants at Calbecht and Pegnitz.

Industrial tests on a Kachkanarsk ore concentrate N. F. Dubrov (*Stal'*, 1959, (6), 501) A note on research at the Ural Ferrous Metal Institute. Sinter production and blast-furnace use was tried and the iron produced was blown in a converter. The ore contains 0·13–0·16%V and 90–93% passed into the slag.

Products obtained in the thermal decomposition of minerals having the kaolinite structure J. Babčan (*Silikáty*, 1959, **3,** (1), 20–25) Chlorites having the kaolinite structure were found to be partially reduced on heating in hydrogen at 500°C, with liberation of metallic iron. Not all the iron contained in the minerals is, however, reduced to the metal.—P.F.

Results of experimental roasting of Soviet fine pyrites and low-sulphur pyrites from Elbingerode in the fluidized roasting furnace E. Theurich and W. Zimmer (*Neue Hütte*, 1959, **4,** Apr., 232–237) Experimental results in the operation of the furnace on these two types of pyrites show that it is suitable for the purpose. The results obtained are discussed.

Open-hearth sinter from Dashkesansk ores V. K. Yatsura (*Stal'*, 1959, (6), 525) A suitable composition is given.

Experiences on material testing in the ore sintering plant in Dunapentele, Hungary L. Pozze and K. Keztyús (*Koh. Lapok*, 1959, **14,** Feb.–March, 108–112) The authors describe the sampling and testing methods used in the ore sintering plant at Dunapentele, Hungary. Chemical analysis of the raw materials and of the sintered products, and the 'trommel test' on the sintered products, the latter for the determination of strength, are performed. The FeO content increases, and the basicity (i.e. the ratio $CaO:SiO_2$) decreases the strength of the sintered products.—P.K.

Setting processes during the solidification of briquettes from ore lime coke mixtures under different conditions K. Stulpnagel and G. von Struve (*Neue Hütte*, 1959, **5,** May, 298–304) Cylindrical briquettes from mixtures of ore, lime, and coke from German sources were dried under various conditions, and the resultant increase in hardness examined. The setting process was explained in the light of pH measurements, mineralogical examination, microhardness tests, X-ray investigation, and differential thermal analysis.

Preparation of fluxed sinter from manganese ores A. I. Soldatkin (*Stal'*, 1955, (6), 497–505) By treating Chiatura manganese ores with lime, a fully satisfactory fluxed sinter may be obtained. The optimum conditions for the process are: 350–400 mm thickness of the charge layer, 7–8% moisture; 5% carbon content and a grain size of 0–5 mm for the crushed flux and 0–4 mm for the coke. Under these conditions practically the whole of the lime combines chemically with the metal-free gangue.

New 5000 tons per day ore sintering plant at U.S. Steels Ohio works (*Ind. Heat.*, 1959, **26,** Jan., 86–94) The units and operation of this plant are described. One item of interest is the 'flying saucer' (an inclined, rotating, saucer shaped disc) which blends and pelletizes the materials before sintering.—D.L.C.P.

Firing pellets on a grate I. I. Robenskii (*Stal'*, 1959, (5), 389–393) Magnetite concentrate pellets were hardened experimentally by firing with high-calorific gas. The pellets were fluxed with limestone and a cooling zone was found to be an advantage. Trials with solid fuel firing were also made. Temperatures, fuel and air flow rates, bed dimensions, and the properties of the fired pellets are given.

Production of open-hearth sinter from local ores at the Kuznetsk Combine K. F. Marchenko (*Stal'*, 1959, (4), 311–313) The compositions of the ores and the mixtures and processes used and the product are described.

Use of multi-cyclones on sinter machines A. K. Rudkov (*Stal'*, 1959, (3), 209–210) Investigations of the dust-catching devices for protection of the fan blades are described. The rotors of 3500 m^3/min capacity can run for 3 years and this can be increased further with better gas cleaning.

Continuous burning of limestone for the sinter mix G. G. Oreshkin, N. Z. Plotkin and A. K. Rudkov (*Stal'*, 1959, (3), 197–203) A continuous rotary kiln for direct inclusion in the sinter equipment is described. It revolves in 5–18 min giving a calcination period of 5–15 min. It produces 150 t/day from a charge ground to 0–10 mm. Costs are indicated.

FUEL-PREPARATION, PROPERTIES AND USES

Radiometric measurement of the lumpiness of skip coke I. G. Polovchenko, V. N. Afanas'ev, V. N. Uzlyuk and A. L. Berin (*Stal'*, 1959, (3), 211) A method using γ-rays is described, the absorption depending mainly on the voids. The absorption is measured in the weighing hopper and correlations with size and furnace-operation have been constructed.

Coal treatment K. G. Beck (*BWK*, 1959, **11,** April 5, 153–155) A review of the literature published in 1957 and 1958 dealing with the composition, beneficiation, coking, and by-product production (50 refs.).

The preparation of coal for carbonization W. H. Griffiths (*Inst. Nac. Carbon Bol. Inf.*, 1958, **7,** Sept.–Oct., 213–226) The desired low ash and sulphur contents, and the optimum moisture content for coking coals are obtainable by suitable treatments, which are discussed. Difficulties associated with the nature of the seams to be worked and increasing mechanization are dealt with.

Anti-dust treatment of coal and coke W. Fries (*Glückauf*, 1959, **95,** April 25, 489–501) Laboratory tests carried out by Ruhrkohlen-Beratung of Essen on the binding of dust by spraying and the successful application of the method to the treatment of briquettes are described in detail (53 refs.).

Construction of large coke-chemical plants B. A. Raskin (*Koks i Khimiya*, 1958, (8), 45–48; from *Techn. Translations*, 1959, **1,** April 3, 232; *PB* 141308T) An analysis of the economics of extending existing plants or enlarging the volume of the batteries. The optimum appears to be the extension of existing batteries to 6–8 per plant and increase of effective volume from 30 to 32 ft^3.

Waste gas temperatures of coke ovens A. Steding (*Glückauf*, 1959, **95,** March 28, 400–404) After pointing out that the waste gas temperatures in modern coke ovens fired with high-calorific gas are substantially below calculated temperatures, the author discusses the thermal conditions with top and under-fired ovens, using high and low calorific value gases.

The effect of coking technology on coke quality J. Kunc and J. Holub (*Paliva*, 1959, **39,** (2), 45–47) The effect of the method of filling coke-ovens, e.g. simple pouring, or stamping, on the quality of the coke was investigated experimentally with several types of coal mined in the Ostrava basin. A high packing density is generally preferable with badly coking coals and vice versa, but a few exceptions to the rule were found.—F.F.

Estimation of the optimum ash content of metallurgical coke and of the optimum moisture content of coking coal K. Lemke (*Inst. Nac. Carbon Bol. Inf.*, 1958, **7,** Sept.–Oct., 189–202) Costs for reducing the ash content of blast furnace coke and the moisture content of the coking coal to < 10% in each case were calculated for three unwashed coals, and the results evaluated.

Coal preparation in connexion with its utilization in the coke oven J. Goffart and J. Stienon (*Inst. Nac. Carbon Bol. Inf.*, 1958, **7,** Sept.–Oct., 189–202) Economic factors in connexion with the preparation and coking of Belgian coal are considered. In particular the effect of ash content on coke consumption in the blast furnace and on coke oven yields are examined.

New instruments for the investigation of gases and determination of their calorific value, and for the control of furnace installations W. Eickler (*Gas-Wärme*, 1957, Nov., 348–351) Several of these instruments are described including the Kalorex, Barex S, and Combustrex equipment.

On heat radiation from flames of industrial gases W. Pepperhoff (*Stahl Eisen*, 1959, **79,** May 14, 729–730) This is a review of a dissertation by W. Fries on radiation effects of flames. CO, H_2, CH_4, C_2H_6, C_4H_{10}, and C_2H_4 were studied. The radiation is mainly determined by the number of carbon particles in the flame.

REFRACTORY MATERIALS

Between two fires. Railways carry refractories from brick kiln to blast furnace (*Transport Age*, 1959, **2,** April, 9–13) Pallet handling of bricks and 'Palbrick' railway wagon design are described.

Ramming of ladle linings F. Stebel (*Hutník*, 1959, **9,** (4), 129–132) The use of 'Ladelite' and other natural and synthetic mixtures for lining ladles is discussed. Experiments with various mixtures of sands and clays were carried out on small steelworks ladles. The final composition lay somewhat below the eutectoid point of the SiO_2–Al_2O_3 system, and had a life equal to that obtained currently with more expensive firebrick linings.—P.F.

Practical test of special silica bricks. (Silica bricks containing Cr_2O_3) K. Nagami and K. Isoda (*Tetsu to Hagane*, 1959, **45,** April, 397–403) OH bricks containing 8% Cr_2O_3 have a higher resistance to iron oxide absorption than common silica bricks. Tests showed that these bricks exhibited 36–64% less corrosion than high-alumina bricks on the lower part of the side wall of the uptake, 59–70% less than silica bricks on the walls of the slag chamber, and 50% less in the slag-chamber arch.—K.E.J.

The quality of ladle-bricks in steel plants F. Nagy (*Koh. Lopok*, 1959, **14,** Feb.–March, 70–76) The author compares the chemical composition and physical properties of ladle bricks used in steel plants in Italy, Great Britain, USA, Czechoslovakia, USSR, Germany, and Hungary. In the last mentioned, the best results have been obtained with semi-acid bricks of the following chemical composition: SiO_2 73·0%, Al_2O_3 23·0%, TiO_2 1·44%, Fe_2O_3 1·80%, CaO 0·80%.—P.K.

Evaluation of the hot 'vitreous phase' E. De Geyndt and P. Angenot (*Chem. Week.*, 1959, **55,** April 4, 145–149) [In French] A modified method is described for determining the vitreous phase of refractories at high temperatures; it consists of heating the specimen between two porous discs which absorb the phase, and determining the loss in weight.

Study on the corrosion mechanism of refractories used in a zebra roof of a basic open-hearth furnace T. Ao and T. Oyama (*Tetsu to Hagane*, 1959, **45,** Feb., 93–99) A conventional silica brick and a metal-encased chrome-magnesite unburned brick, placed adjacent, were taken from the roof after 402 heats and examined. The high content of iron oxide in the hottest part of the silica brick may be from decomposition of ferrous silicate. In the hotter areas, iron oxide and magnesia had migrated to the matrix of the silica brick, and siliceous liquid into the basic brick. A mechanism for the destruction of spinel is suggested (12 refs.)—K.E.J.

IRON AND STEEL—GENERAL

The iron and steel industry: its present expansion C. J. Martinez (*Ing. e Indust.*, 1959, **26,** April, 74–78, 94) [In Spanish] Reasons for the growth of the industry are discussed and it is pointed out that the present expansion has two aspects: all the under-developed countries are making very strong efforts to establish their own industries and the others are taking steps to increase their own production. Problems of transport and supply of raw materials influence expansion as well as the techniques of steelmaking. It is shown that the industry is no longer based on native raw materials but is becoming international and so improved quality and decreased costs are fundamental factors for expansion of the internal market and competition in the others.—P.S.

The Soviet iron and steel industry (*Mét. Constr. Méc.*, 1959, **91,** April, 237–247) This section gives a general outline of the organization of the Soviet iron and steel industry, location of the main centres and techniques employed.

Metallurgy in the USSR J. H. Hollomon (*Met. Prog.*, 1959, **75,** Jan., 120–123) A résumé of a visit to Russia, dealing, *inter alia*, with steelmaking and the organization of research.

Realization of the decisions of the Party G. Oreshkin (*Stal'*, 1959, (3), 193–196) An account of the plans for the development of the industry under the new seven-year plan.

The leap forward of Chinese iron and steelmaking G. Grenier (*Echo Mines*, 1959, April, 221–224) An illustrated account of the Chinese miniature blast furnaces and convertors.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

Air cooling of blast furnaces A. A. Razumov (*Stal'*, 1959, (4), 304–305) A proposed design for plate underhearth air coolers to replace tubular designs is described. Air versus water cooling is discussed. The advantages of the more expensive air cooling being regarded as decisive. The outlet air temperature can be used in automatic furnace control.

Blast-furnace burden preparation when using high-ash coke R. F. Jennings and A. M. Frankau (*Iron Coal Trades Rev.*, 1959, **178,** June 5, 1317–1320) An account of Indian conditions. Coke rate should be reduced until slag volume is at the minimum workable limit. Crushing of the ore with screening out of the fines is suggested, the fines being sintered with the highest possible lime content to reduce the charge of uncalcined limestone to the furnace. Experience elsewhere suggests a charge of 60% crushed ore and 40% sinter.

Design, maintenance, and operation of two-pass checkers J. Anderton (430–448) An illustrated account of Broken Hill Proprietary Co. experience is given. Dimensions are fully tabulated and brick replacement schedules are shown. Construction, cleaning, and performance are discussed.

PROPERTIES, TREATMENT AND USE OF SLAGS

Utilization of granulated slags for producing heavy panelling and cast partitions K. I. Khokholev (Translated from '*Experience in the use of blast furnace granulated slags in structural work*', Chapter IV) Wall partitions and panels of slag, plaster, and a retarding agent are produced by casting in plant which is described, especially for use in timberless regions. Full details of moulds and mixes and of trials with setting retarders are given.

The activity coefficient of manganese (II) oxide and iron (II) oxide in open-hearth slag M. G. Frohberg (*Stahl Eisen*, 1959, **79,** July 23, 1085–1086) A review of published information on the activity coefficients of FeO and MnO in OH slag. It is concluded that MnO has a greater effect on the basicity of OH slags compared with FeO than is usually assumed.—T.G.

DIRECT PROCESSES

Direct smelting of iron ores, I S. Nagata and T. Sugiyama (*Denki-Seiko*, 1959, **30,** Jan., 129–138) [In Japanese] A review, giving details of the Höganäs, R-N (Republic Steel–National Lead), Wiberg-Söderfors, Norsk–Staal, Maderas, H-iron, Esso-Little, US Steel (Shipley or Nu-iron), Krupp-Renn, and BISRA (Cyclosteel) processes.—K.E.J.

Steels made with ordinary iron ore and natural gas A. Cresta (*Tecn. Indust.*, 1959, **37,** May, 611–614) [In Spanish] The author suggests that the San Nicholas's plant will be out of date before it is completed because of the development of the direct reduction process. Natural gas, desulphurized and reformed, will be used to reduce the ore and heat the OH furnaces. The present position and future

development of the process is discussed. Since about 590 m^3 of natural gas is needed for each t of steel, the cost of this will influence the location of future plant and the Puerto Madryn region is forecast as the future metallurgical centre of the Argentine.—P.S.

PRODUCTION OF STEEL

Progress in German steelmaking H. W. Balster (*Met. Prog.*, 1959, **75,** Jan., 116–119) A short review of the latest developments taking place in the German iron and steel industry. Ore will be imported on a large scale from Conakry. Energy savings are being made by hot-cooling. The output of the blast furnaces has increased, new processes are applied to steelmaking, and more and more continuous casting plants are being erected.—T.G.

The development of the use of oxygen in Czechoslovak steelworks A. Děkanovský (*Hutn. Listy*, 1958, **13,** (11), 965–969) Oxygen plants are being built at all the larger steelworks for completion not later than 1960. O_2 will then be used not only in the OH furnace using a liquid charge, but in all the new 400-t OH furnaces now under construction. The use of O_2 in converter practice will also make high demands on the supply of O_2, and the erection of cheap nuclear power plants for O_2 production is proposed.—P.F.

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The physical chemistry of steelmaking J. F. Elliott (*Proceedings of the Conference sponsored by the Dept. of Metallurgy, Massachusetts Institute of Technology*, 1956, *Dedham, Mass.*, 1958, pp.257) **Activity of carbon in liquid iron-carbon solutions** A. Rist and J. Chipman (3–12) The activity was measured by accurate gas analysis of equilibrated CO–CO_2 mixtures with the alloy in apparatus described. Sources of error are discussed and the data is interpreted. **Activity of carbon in molten Fe C alloys at high carbon content – a progress report** J. A. Cordier and P. P. Kozakevitch (13–14) Work at IRSID in which H_2 is bubbled through the melt with formation essentially of methane is outlined. **The distribution of alloying elements between molten iron and silver** G. Derge (15–17) Cu, Mn, S and their combinations, and the effect of C have been studied. **An adiabatic dropping calorimeter for enthalpy measurements at high temperatures. The heat content of silicon from 1200° to 1550° C** M. Olette (18–26) Samples heated in a furnace are dropped into a copper calorimeter. Apparatus is described and sample preparation and calibration procedures are given. The m.p. of Si (1412 ± 2°C) and its heat of fusion (12·095 ± 100 cal) and its enthalpy in the solid and liquid states were determined. **Surface tension of pure liquid iron, cobalt, and nickel at 1550° C** P. P. Kozakevitch and G. Urbain (27–34) Measurements were made by the sessile drop method. The surface tension of Fe at 1550°C was 1835 dyne/cm^{-1}. **The carbon-oxygen equilibria in liquid iron** J. F. Elliott (37–41) Various data for a temp. of ~1600°C are assembled. **Equilibrium of carbon and oxygen in molten iron saturated with carbon-II. The effect of silicon in the range of 0 5 2%** S. Matoba and S. Ban-Ya (42–45) Fe-Si alloys equilibrated with CO–CO_2 were quenched and analysed; activities were calculated and the effects of other elements were determined. **The alumina-graphite reaction in liquid iron and the aluminium deoxidation constant in steelmaking** J. Chipman and F. C. Langenberg (46–50) Slags were equilibrated with graphite-saturated Fe–C–Si–Al melts at 1600° and 1700°C and Al_2O_3 dissociation was studied. Oxygen activity was evaluated and the Al deoxidation constant was found to be 3·6 × 10^{-14} at 1600° and 2·8 × 10^{-13} at 1700°C. **The determination of oxygen and nitrogen in metals by fusion in vacuum (discussion)** N. A. Gokcen (51–52). **Formation and destruction of foams and emulsions in iron and steelmaking** P. P. Kozakevitch (89–92) Factors favouring foaming and emulsification are enumerated and foaming slags and metal emulsification in slags are considered. **Slag metal reactions of chromium in carbon-saturated melts** C. W. McCoy and W. O. Philbrook (93–98) The reduction of Cr from CaO–SiO_2–Al_2O_3 slags by C-saturated Fe is found to be a first order reaction with respect to Cr, and independent of temp. in the range 1500–1650°C and of slag basicity in the range CaO : SiO_2 = 0·6–2·5. Under these conditions the Cr is bivalent. Cr_7C_3 is formed by a different mechanism at a slower rate, and is insoluble in slag but soluble in C-saturated Fe up to 14%Cr. Recovery ought to be complete under blast furnace hearth conditions. **Kinetics of metallurgical reactions with particular reference to the open hearth** L. S. Darken (101–108) The idea of local equilibrium is developed and reaction rates are shown to depend upon nucleation or diffusion. The conditions during boil are developed and discussed. **Theory of degassing of the open-hearth bath during carbon boil** P. Vallet (109–112) Gellers' theory is discussed and a modified set of equations are derived. **Kinetic factors in the desulphurization of pig iron by blast-furnace type slags** J. C. Fulton and J. Chipman (113–116) Experiments in a stirred graphite crucible in an atmosphere of CO are reported. The great accelerating effect of Si in the bath is shown. **The deoxidation of iron melts with silicon** W. A. Fischer (117–122) Iron melts were sampled at 30 s intervals after Si addition and changes in O and Si were followed. The process and products of deoxidation are examined. **Electrochemical nature of sulphur transfer in the system carbon-saturated iron slag** T. B. King and S. Ramachandran (125–135) Experiments were made in a rotating graphite crucible and S transfer from metal to slag and CO evolution were measured. The reactions are then formulated and the mechanisms considered. **The desulphurization and dephosphorization of carbon-saturated iron** C. E. A. Shanahan (136–141) Data are given showing that the rate of S removal can be very high if the interface area has a high ratio to metal volume. Two mechanisms for P removal are proposed, one suggesting that the C–O–CO reactor is sluggish and the other assuming the metal around an O_2 bubble to be out of equilibrium with the melt. **The effect of**

Production of open-hearth sinter from local ores at the Kuznetsk Combine K. F. Marchenko (*Stal'*, 1959, (4), 311–313) The compositions of the ores and the mixtures and processes used and the product are described.

Use of multi-cyclones on sinter machines A. K. Rudkov (*Stal'*, 1959, (3), 209–210) Investigations of the dust-catching devices for protection of the fan blades are described. The rotors of 3500 m^3/min capacity can run for 3 years and this can be increased further with better gas cleaning.

Continuous burning of limestone for the sinter mix G. G. Oreshkin, N. Z. Plotkin and A. K. Rudkov (*Stal'*, 1959, (3), 197–203) A continuous rotary kiln for direct inclusion in the sinter equipment is described. It revolves in 5–18 min giving a calcination period of 5–15 min. It produces 150 t/day from a charge ground to 0–10 mm. Costs are indicated.

FUEL-PREPARATION, PROPERTIES AND USES

Radiometric measurement of the lumpiness of skip coke I. G. Polovchenko, V. N. Afanas'ev, V. N. Uzlyuk and A. L. Berin (*Stal'*, 1959, (3), 211) A method using γ-rays is described, the absorption depending mainly on the voids. The absorption is measured in the weighing hopper and correlations with size and furnace-operation have been constructed.

Coal treatment K. G. Beck (*BWK*, 1959, **11**, April 5, 153–155) A review of the literature published in 1957 and 1958 dealing with the composition, beneficiation, coking, and by-product production (50 refs.).

The preparation of coal for carbonization W. H. Griffiths (*Inst. Nac. Carbon Bol. Inf.*, 1958, **7**, Sept.–Oct., 213–226) The desired low ash and sulphur contents, and the optimum moisture content for coking coals are obtainable by suitable treatments, which are discussed. Difficulties associated with the nature of the seams to be worked and increasing mechanization are dealt with.

Anti-dust treatment of coal and coke W. Fries (*Glückauf*, 1959, **95**, April 25, 489–501) Laboratory tests carried out by Ruhrkohlen-Beratung of Essen on the binding of dust by spraying and the successful application of the method to the treatment of briquettes are described in detail (53 refs.).

Construction of large coke-chemical plants B. A. Raskin (*Koks i Khimiya*, 1958, (8), 45–48; from *Techn. Translations*, 1959, **1**, April 3, 232; *PB* 141308T) An analysis of the economics of extending existing plants or enlarging the volume of the batteries. The optimum appears to be the extension of existing batteries to 6–8 per plant and increase of effective volume from 30 to 32 ft^3.

Waste gas temperatures of coke ovens A. Steding (*Glückauf*, 1959, **95**, March 28, 400–404) After pointing out that the waste gas temperatures in modern coke ovens fired with high-calorific gas are substantially below calculated temperatures, the author discusses the thermal conditions with top and underfired ovens, using high and low calorific value gases.

The effect of coking technology on coke quality J. Kunc and J. Holub (*Paliva*, 1959, **39**, (2), 45–47) The effect of the method of filling coke-ovens, e.g. simple pouring, or stamping, on the quality of the coke was investigated experimentally with several types of coal mined in the Ostrava basin. A high packing density is generally preferable with badly coking coals and vice versa, but a few exceptions to the rule were found.—P.F.

Estimation of the optimum ash content of metallurgical coke and of the optimum moisture content of coking coal K. Lemke (*Inst. Nac. Carbon Bol. Inf.*, 1958, **7**, Sept.–Oct., 189–202) Costs for reducing the ash content of blast furnace coke and the moisture content of the coking coal to $< 10\%$ in each case were calculated for three unwashed coals, and the results evaluated.

Coal preparation in connexion with its utilization in the coke oven J. Goffart and J. Stienon (*Inst. Nac. Carbon Bol. Inf.*, 1958, **7**, Sept.–Oct., 189–202) Economic factors in connexion with the preparation and coking of Belgian coal are considered. In particular the effect of ash content on coke consumption in the blast furnace and on coke oven yields are examined.

New instruments for the investigation of gases and determination of their calorific value, and for the control of furnace installations W. Eickler (**Gas-Wärme*, 1957, Nov., 348–351) Several of these instruments are described including the Kalorex, Barex S, and Combustrex equipment.

On heat radiation from flames of industrial gases W. Pepperhoff (*Stahl Eisen*, 1959, **79**, May 14, 729–730) This is a review of a dissertation by W. Fries on radiation effects of flames. CO, H_2, CH_4, C_2H_8, C_4H_{10}, and C_2H_4 were studied. The radiation is mainly determined by the number of carbon particles in the flame.

REFRACTORY MATERIALS

Between two fires. Railways carry refractories from brick kiln to blast furnace (*Transport Age*, 1959, **2**, April, 9–13) Pallet handling of bricks and 'Palbrick' railway wagon design are described.

Ramming of ladle linings F. Stebel (*Hutník*, 1959, **9**, (4), 129–132) The use of 'Ladelite' and other natural and synthetic mixtures for lining ladles is discussed. Experiments with various mixtures of sands and clays were carried out on small steelworks ladles. The final composition lay somewhat below the eutectoid point of the SiO_2–Al_2O_3 system, and had a life equal to that obtained currently with more expensive firebrick linings.—P.F.

Practical test of special silica bricks. (Silica bricks containing Cr_2O_3) K. Nagami and K. Isoda (*Tetsu to Hagane*, 1959, **45**, April, 397–403) OH bricks containing 8% Cr_2O_3 have a higher resistance to iron oxide absorption than common silica bricks. Tests showed that these bricks exhibited 36–64% less corrosion than high-alumina bricks on the lower part of the side wall of the uptake, 59–70% less than silica bricks on the walls of the slag chamber, and 50% less in the slag-chamber arch.—K.E.J.

The quality of ladle-bricks in steel plants F. Nagy (*Koh. Lopok*, 1959, **14**, Feb.–March, 70–76) The author compares the chemical composition and physical properties of ladle bricks used in steel plants in Italy, Great Britain, USA, Czechoslovakia, USSR, Germany, and Hungary. In the last mentioned, the best results have been obtained with semi-acid bricks of the following chemical composition: SiO_2 73·0%, Al_2O_3 23·0%, TiO_2 1·44%, Fe_2O_3 1·80%, CaO 0·80%.—P.K.

Evaluation of the hot 'vitreous phase' E. De Geyndt and P. Angenot (*Chem. Week.*, 1959, **55**, April 4, 145–149) [In French] A modified method is described for determining the vitreous phase of refractories at high temperatures; it consists of heating the specimen between two porous discs which absorb the phase, and determining the loss in weight.

Study on the corrosion mechanism of refractories used in a zebra roof of a basic open-hearth furnace T. Ao and T. Oyama (*Tetsu to Hagane*, 1959, **45**, Feb., 93–99) A conventional silica brick and a metal-encased chrome-magnesite unburned brick, placed adjacent, were taken from the roof after 402 heats and examined. The high content of iron oxide in the hottest part of the silica brick may be from decomposition of ferrous silicate. In the hotter areas, iron oxide and magnesia had migrated to the matrix of the silica brick, and siliceous liquid into the basic brick. A mechanism for the destruction of spinel is suggested (12 refs.)—K.E.J.

IRON AND STEEL—GENERAL

The iron and steel industry: its present expansion C. J. Martinez (*Ing. e Indust.*, 1959, **26**, April, 74–78, 94) [In Spanish] Reasons for the growth of the industry are discussed and it is pointed out that the present expansion has two aspects: all the under-developed countries are making very strong efforts to establish their own industries and the others are taking steps to increase their own production. Problems of transport and supply of raw materials influence expansion as well as the techniques of steelmaking. It is shown that the industry is no longer based on native raw materials but is becoming international and so improved quality and decreased costs are fundamental factors for expansion of the internal market and competition in the others.—P.S.

The Soviet iron and steel industry (*Mét. Constr. Méc.*, 1959, **91**, April, 237–247) This section gives a general outline of the organization of the Soviet iron and steel industry, location of the main centres and techniques employed.

Metallurgy in the USSR J. H. Hollomon (*Met. Prog.*, 1959, **75**, Jan., 120–123) A résumé of a visit to Russia, dealing, *inter alia*, with steelmaking and the organization of research.

Realization of the decisions of the Party G. Oreshkin (*Stal'*, 1959, (3), 193–196) An account of the plans for the development of the industry under the new seven-year plan.

The leap forward of Chinese iron and steelmaking G. Grenier (*Echo Mines*, 1959, April, 221–224) An illustrated account of the Chinese miniature blast furnaces and convertors.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

Air cooling of blast furnaces A. A. Razumov (*Stal'*, 1959, (4), 304–305) A proposed design for plate underhearth air coolers to replace tubular designs is described. Air versus water cooling is discussed. The advantages of the more expensive air cooling being regarded as decisive. The outlet air temperature can be used in automatic furnace control.

Blast-furnace burden preparation when using high-ash coke R. F. Jennings and A. M. Frankau (*Iron Coal Trades Rev.*, 1959, **178**, June 5, 1317–1320) An account of Indian conditions. Coke rate should be reduced until slag volume is at the minimum workable limit. Crushing of the ore with screening out of the fines is suggested, the fines being sintered with the highest possible lime content to reduce the charge of uncalcined limestone to the furnace. Experience elsewhere suggests a charge of 60% crushed ore and 40% sinter.

Design, maintenance, and operation of two-pass checkers J. Anderton (430–448) An illustrated account of Broken Hill Proprietary Co. experience is given. Dimensions are fully tabulated and brick replacement schedules are shown. Construction, cleaning, and performance are discussed.

PROPERTIES, TREATMENT AND USE OF SLAGS

Utilization of granulated slags for producing heavy panelling and cast partitions K. I. Khokholev (Translated from '*Experience in the use of blast furnace granulated slags in structural work*', Chapter IV) Wall partitions and panels of slag, plaster, and a retarding agent are produced by casting in plant which is described, especially for use in timberless regions. Full details of moulds and mixes and of trials with setting retarders are given.

The activity coefficient of manganese (II) oxide and iron (II) oxide in open-hearth slag M. G. Frohberg (*Stahl Eisen*, 1959, **79**, July 23, 1085–1086) A review of published information on the activity coefficients of FeO and MnO in OH slag. It is concluded that MnO has a greater effect on the basicity of OH slags compared with FeO than is usually assumed.—T.G.

DIRECT PROCESSES

Direct smelting of iron ores, I S. Nagata and T. Sugiyama (*Denki-Seiko*, 1959, **30**, Jan., 129–138) [In Japanese] A review, giving details of the Höganäs, R-N (Republic Steel–National Lead), Wiberg-Söderfors, Norsk-Staal, Maderas, H-iron, Esso-Little, US Steel (Shipley or Nu-iron), Krupp-Renn, and BISRA (Cyclosteel) processes.—K.E.J.

Steels made with ordinary iron ore and natural gas A. Cresta (*Tecn. Indust.*, 1959, **37**, May, 611–614) [In Spanish] The author suggests that the San Nichola's plant will be out of date before it is completed because of the development of the direct reduction process. Natural gas, desulphurized and reformed, will be used to reduce the ore and heat the OH furnaces. The present position and future

development of the process is discussed. Since about 590 m^3 of natural gas is needed for each t of steel, the cost of this will influence the location of future plant and the Puerto Madryn region is forecast as the future metallurgical centre of the Argentine.—P.S.

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The drive for high-grade steel M. Pertsev (*Stal'*, 1958, (2), 97–100) An account of the foundation and development of the Hammer and Sickle works with a brief description.

Petroleum techniques for steel F. D. Hoffert, E. A. Kelly, and A. M. Squires (*Mech. Eng.*, 1959, **81,** Jan., 27–30) An account of the H-iron process.

The physical chemistry of steelmaking J. F. Elliott (*Proceedings of the Conference sponsored by the Dept. of Metallurgy, Massachusetts Institute of Technology*, 1956, *Dedham, Mass.*, 1958, pp.257) **Activity of carbon in liquid iron-carbon solutions** A. Rist and J. Chipman (3–12) The activity was measured by accurate gas analysis of equilibrated CO–CO_2 mixtures with the alloy in apparatus described. Sources of error are discussed and the data is interpreted. **Activity of carbon in molten Fe C alloys at high carbon content – a progress report** J. A. Cordier and P. P. Kozakevitch (13–14) Work at IRSID in which H_2 is bubbled through the melt with formation essentially of methane is outlined. **The distribution of alloying elements between molten iron and silver** G. Derge (15–17) Cu, Mn, S and their combinations, and the effect of C have been studied. **An adiabatic dropping calorimeter for enthalpy measurements at high temperatures. The heat content of silicon from 1200° to 1550° C** M. Olette (18–26) Samples heated in a furnace are dropped into a copper calorimeter. Apparatus is described and sample preparation and calibration procedures are given. The m.p. of Si (1412 ± 2°C) and its heat of fusion (12·095 ± 100 cal) and its enthalpy in the solid and liquid states were determined. **Surface tension of pure liquid iron, cobalt, and nickel at 1550° C** P. P. Kozakevitch and G. Urbain (27–34) Measurements were made by the sessile drop method. The surface tension of Fe at 1550°C was 1835 dyne/cm^{-1}. **The carbon-oxygen equilibria in liquid iron** J. F. Elliott (37–41) Various data for a temp. of ~1600°C are assembled. **Equilibrium of carbon and oxygen in molten iron saturated with carbon-II. The effect of silicon in the range of 0·5–2%** S. Matoba and S. Ban-Ya (42–45) Fe-Si alloys equilibrated with CO–CO_2 were quenched and analysed; activities were calculated and the effects of other elements were determined. **The alumina-graphite reaction in liquid iron and the aluminium deoxidation constant in steelmaking** J. Chipman and F. C. Langenberg (46–50) Slags were equilibrated with graphite-saturated Fe–C–Si–Al melts at 1600° and 1700°C and Al_2O_3 dissociation was studied. Oxygen activity was evaluated and the Al deoxidation constant was found to be 3·6 × 10^{-14} at 1600° and 2·8 × 10^{-13} at 1700°C. **The determination of oxygen and nitrogen in metals by fusion in vacuum (discussion)** N. A. Gokcen (51–52). **Formation and destruction of foams and emulsions in iron and steelmaking** P. P. Kozakevitch (89–92) Factors favouring foaming and emulsification are enumerated and foaming slags and metal emulsification in slags are considered. **Slag–metal reactions of chromium in carbon-saturated melts** C. W. McCoy and W. O. Philbrook (93–98) The reduction of Cr from CaO–SiO_2–Al_2O_3 slags by C-saturated Fe is found to be a first order reaction with respect to Cr, and independent of temp. in the range 1500–1650°C and of slag basicity in the range CaO : SiO_2 = 0·6–2·5. Under these conditions the Cr is bivalent. Cr_7C_3 is formed by a different mechanism at a slower rate, and is insoluble in slag but soluble in C-saturated Fe up to 14% Cr. Recovery ought to be complete under blast furnace hearth conditions. **Kinetics of metallurgical reactions with particular reference to the open hearth** L. S. Darken (101–108) The idea of local equilibrium is developed and reaction rates are shown to depend upon nucleation or diffusion. The conditions during boil are developed and discussed. **Theory of degassing of the open-hearth bath during carbon boil** P. Vallet (109–112) Gellers' theory is discussed and a modified set of equations are derived. **Kinetic factors in the desulphurization of pig iron by blast-furnace type slags** J. C. Fulton and J. Chipman (113–116) Experiments in a stirred graphite crucible in an atmosphere of CO are reported. The great accelerating effect of Si in the bath is shown. **The deoxidation of iron melts with silicon** W. A. Fischer (117–122) Iron melts were sampled at 30 s intervals after Si addition and changes in O and Si were followed. The process and products of deoxidation are examined. **Electrochemical nature of sulphur transfer in the system carbon-saturated iron slag** T. B. King and S. Ramachandran (125–135) Experiments were made in a rotating graphite crucible and S transfer from metal to slag and CO evolution were measured. The reactions are then formulated and the mechanisms considered. **The desulphurization and dephosphorization of carbon-saturated iron** C. E. A. Shanahan (136–141) Data are given showing that the rate of S removal can be very high if the interface area has a high ratio to metal volume. Two mechanisms for P removal are proposed, one suggesting that the C–O–CO reactor is sluggish and the other assuming the metal around an O_2 bubble to be out of equilibrium with the melt. **The effect of**

temperature and silica on the dephosphorization of iron with lime G. Trömel (142–146). **Some Swedish experiences of the importance of physical chemistry for the development of process metallurgy** B. Kalling (149–158) Examples are drawn from ore reduction, blast-furnace operation, external pig-iron desulphurization, decarburization of solid pig-iron, acid OH working and the basic OH process (30 refs). **Gas utilization in the reduction of iron oxides** G. St. Pierre (159–164) It is concluded that optimum reaction temperatures exist for which the utilization of CO–H_2 mixtures in iron oxide reduction is a maximum and that maximum gas utilization is accomplished with low reaction temperatures for CO-rich mixtures and with high temperatures for H_2-rich mixtures. The poorest utilization is with 55%H_2–45%CO and improvement is effected by passage towards 100% of either. **The study of slag metal mixing efficiency by models** C. E. A. Shanahan (165–172) Studies with Hg–dilute acid systems are reported, mixing by gas blowing, by pouring, by mixing with a rabble and by bottom blowing through 3 holes. Pouring 'metal' into 'slag' appeared to be the most effective method. **The chemical equilibrium in the basic Bessemer process** A. M. Decker (173–178) The questions of Mn, P, O, and S were successively studied in relation to the activity of iron oxide and a state of equilibrium appears to exist at the end of the blow. Slag analyses give data from which the residual Mn, P, O, and S contents of the steel bath can be obtained. **Solidification of steel ingots** M. Tenenbaum (181–193) A description of the solidification process is attempted for ingots, for big-end-up hot-topped ingots and for rimming steels with consideration of the effects of gas formation. **Theoretical study on the solidification progress of ingots of finite dimensions** P. Vallet (194–199) Formulae are given for rectangular, square, circular or regular polygon sections; for cases where the base is insulated and where both ends are insulated and for regular polyhedral or spherical ingots, all by application of Light-foot's law. **The effect of mould geometry on vertical solidification** C. W. Sherman (200–202) Freezing times for straight and tapered 20 × 20 in. square ingots are given. **The importance of the hydrogen content of steel slabs and its determination in sheet steel** C. E. A. Shanahan (203–208) The deleterious influence on ductility, apparently associated with straining of the structure as judged by metallography and load-elongation curves is shown. Much of the H_2 in steel samples of large area is derived from the atmosphere and by assessing this from abrasion studies the H_2 remaining at the slab stage can be estimated. The contribution of this residual gas is negligible. **Solidification of stainless-steel ingots** D. J. Carney and B. R. Queneau (209–215) Specially cast ingots were sectioned and examined for grain size. Additions of metal powders produced grain refinement by nucleation in ferritic types but in austenitic steels the effects were less consistent, apparently on account of the long freezing range. **On segregation in steel castings** C. M. Adams jun. (216–217) Processes are briefly discussed and examples are illustrated. **Summary of needs for fundamental research** F. D. Richardson (221–224) [**Short notes and commentaries**] (225–234). **Kinetic problems of steelmaking** C. Wagner (237–251) Metal-slag reactions, transport-controlled reactions between liquid phases, exchange reactions involving tracer elements, displacement reactions in quasi-binary systems, simultaneous displacement reactions in multicomponent systems and the kinetics of phase-boundary reactions, including silica reduction are discussed and the rate equations given.

Chemistry performance survey of standard alloy steels (*AISI Contrib. Met. Steel*, 1958, Feb., pp.6) Curves for off-heat probabilities for different contents of C, Mn, Ni, Cr, and Mo are given, comparing OH with electric steel furnaces.

Advances at Weirton L. A. Fugassi (*Iron Steel Eng.*, 1959, **36,** Mar., 65–68) An outline is given of the early development and present equipment and capacity of the Weirton Steel Co. plant.

Research on the use of pure oxygen in refining processes P. Metz (*Blast Furn. Steel Plant*, 1958, **46,** Oct., 1065–1069) The work on the use of O_2 in converter processes carried out by the Centre National de Recherches Métallurgiques, Belgium, during the last decade is reviewed (22 refs.).—T.G.

Kaiser's oxygen converter start-up marks completion of expansion program (*Iron Steel Eng.*, 1959, **36,** Mar., 137–138) Some data are given of the Kaiser Steel oxygen converter steelmaking facilities.

The basic oxygen process (*AISI Contrib. Met. Steel*, 1957, Apr., pp.6) Mechanical properties of steels and P, N, and S contents are indicated.

Bessemers used at Lorain to make leaded steel (*Steel*, 1959, **144,** Mar. 30, 82–84) To meet the growing demand 3 acid Bessemer converters are making leaded steel in 60-t heats at the Lorain, Ohio, steelworks. Methods of adding, measuring, and controlling the lead are described.—A.G.

Investigations on basic converter bottoms W. Köhler, T. Hartmann, and G. Trömel (**Stahl Eisen*, 1959, **79,** May 14, 674–683) Fabrication methods and conditions during the service of basic converter bottoms were studied. Lowest porosity required for long life depends on the tar content. The way in which the bottoms wear during service is explained, temperature changes owing to cooling during blowing periods and heating up by radiation during tapping, type of steel produced and iron oxide content and basicity of slag all play their part, the latter two only at temperatures above 1620°C.—T.G.

LD steelmaking in Japan K. Mochizuki (*J. Met.*, 1959, **11,** Mar., 178–180) An account is given of the design and operation of the LD plant installed in 1958 at Kawasaki. Japanese dolomite is used for lining. By 1962 the number of LD converters at Kawasaki and other centres is expected to be 18, with an annual capacity of 4 720 000 metric t.

New melting shop of Ensidesa (*Iron Steel*, 1959, **32,** Mar., 104–105) A description, with an outline diagram, is given of the new Aviles OH plant, consisting of three 350-t tilting furnaces and a 600-t active mixer, with ancillary equipment.

British-built steel plant at Aviles (*Brit. Steel.*, 1959, **25,** Mar., 94–96) A description is given of the three 350-t tilting OH furnace plant recently installed at the Ensidesa works at Aviles, and constructed by a consortium of British steelworks engineering firms.

Melting dynamo steel in 200-ton open-hearth furnaces V. F. Agapov and I. A. Tkachenko (*Stal'*, 1959, (2), 125–128) The development of the process is indicated and the melting of steel with up to 0·06%C and teeming into 7·4-t wide-end-up ladles is described. The Mn must lie between 0·25 and 0·40% to prevent cracking, the use of splash cans 1mm thick is advisable. The temp. 5 min before pouring should be 1585–1600°C (on a noble metal immersion thermocouple) and cracking is reduced when the temp. before deoxidation is 1590°C.

The efficacy of speeding up open-hearth heats by means of oxygen V. N. Kornfel'd (**Stal'*, 1958, (12), 1095–1102) The oxygen fed to the flame per tons charged per m^2 of hearth is used as an index of efficiency in shortening tap-to-tap time as the relative increase in productivity and the relative saving in fuel per m^3 O_2 is proportional to this. The conditions of work and the organization of the shop determine the optimum rate of oxygen feed. At Zaporozhstal use of O_2 in charging and heating up is not expedient. The best rate is 1000–1250 m^3/h during meltdown on scrap and ore if sufficiently rapid slag removal is possible. Where supply is limited it is not always good practice to feed O_2 uniformly in all periods, it is often best to concentrate injection during hot metal addition and melting.—R.S.

The physico-chemical principles involved in desulphurization in the basic open-hearth furnace K. G. Speith, H. vom Ende, F. Bardenheuer, and G. Mahn (**Stahl Eisen*, 1959, **79,** June 25, 926–933) It was found that in the basic OH furnace desulphurization takes place via the limestone dissolved in the slag. High SiO_2 content reduces the ability of the limestone to absorb the sulphur, whereas low iron oxide content in the slag promotes desulphurization. In the liquid slags the sulphur is combined as sulphide but in solidified slags it is found as sulphate, this is due to a reaction with the iron oxide. In the discussion, these findings are disputed, it is stated, *inter alia*, that the sulphur is removed mainly by oxidation.—T.G.

Work sampling: a tool for basic steel management A. G. Holzman (*Blast Furn. Steel Plant.*, 1958, **46,** Oct., 1070–1074) A statistical technique is described for obtaining man and machine delay time as well as activity time. Work sampling, ratio-delay study and occurrence study are the names most commonly applied to this statistical method. An example of an OH furnace is included. The use of computers to perform the calculations after the observations are made is emphasized.—T.G.

Thermodynamics of the reactions of dephosphorization of liquid iron by ferrous–calcareous slag I. Ya. Kozhevnikov (*Stal'*, 1958, (12), 1078–1088) With less than 0·1% of P in the system, phosphate is formed and the stability of this in the slag depends upon the cations present and the type of quasi-crystalline structure. Alkaline earth metal oxides favour P removal as a result of increased thermal effect and the entropy of the reaction.

How photography keeps researchers cool (*Can. Metalw.*, 1959, **22,** Feb., 12) A brief account is given of the use of photography in studying OH furnace reactions. Illustrations are given of the boiling action.—G.F.

The removal of copper from iron copper–carbon melts F. C. Langenberg and R. W. Lindsay (*AISI Contrib. Met. Steel no.51*, pp.47) Three methods of reducing the residual Cu content of Fe–Cu–C melts were investigated, i.e. (1) by utilizing the immiscibility occurring in the presence of high Cu and C; (2) by treatment with Pb, (3) by the use of Na_2S slags. Scope and limitations of each method are discussed (66 refs.).

Examining continuous steel castings C. Varga and J. Fodor (*Atomic World*, 1959, **10,** April, 142–143) Work at the Csepel works in Hungary in which a W ball containing ^{60}Co was dropped into the continuous cast ingot to detect the level of the liquid metal and to find the highest possible cutting point is described. An autoradiograph shows the liquid and pasty zones.

The quality of a 13-ton ingot of 14KhGS steel V. K. Barzii, M. I. Vainshtok, and V. P. Gamazov (*Stal'*, 1959, (5), 456–459) The chemical non-uniformity and the distribution of non-metallic inclusions are determined. Some P and S segregation is found in the top and there is a region of S deficiency in the bottom. Sulphides are mainly in the axial zone and silicates close to the skin at top and bottom.

The segregation zone in ingots of rimming steel Z. Volf (*Hutnik*, 1959, **9,** (1), 13–16) The distribution of segregation and the effect of rolling technology on the distribution was studied on samples taken at all stages of the reduction of 7·7-t ingots, down to the billet stage. The characteristics and extent of segregation in the billet are closely related to segregation in the ingot, which in turn depends on pouring conditions.—P.F.

Studies on the solidification and segregation of larger steel ingots. IV. A unified and systematic interpretation of the mechanism of formation of the three major segregations S. Onodera and Y. Arakida (*Tetsu to Hagane*, 1959, **45,** Jan., 16–21) A general mechanism is proposed to explain the formation of V-shaped, inverted-V, and negative segregations in the ingot; it depends on diffusion and thermal changes as the liquid-solid interface moves inwards (13 refs.).—K.E.J.

On brick inclusion tests by using a CoO tracer K. Nagami, M. Kaya, and S. Katube (*Tetsu to Hagane*, 1958, **44,** Dec., 1365–1372) Inclusions in 450-kg ingots, bottom-poured, of killed steel are investigated using a non-radioactive CoO tracer. The floatability of scums arising from the nozzle, trumpet, and main runner bricks is determined. The quality of the trumpet and main runner bricks should be improved to decrease the inclusions.—K.E.J.

A radioactive tracer study of steel surface defects T. W. Crosta (*AIMME Proc. O.H. Comm.*, 1958, **41**, 193–205) Examination of defective billets at Algoma Steel Corp. has shown that certain surface splits are caused by sub-surface refractory inclusions. The author describes a radioactive tracer study which shows that these inclusions can originate from the hot-top lining and from the refractory stool coating. The conditions most conducive to the entrapment of the inclusions are discussed.

Investigation of blisters under the crust in killed steel V. K. Yatsura (*Stal'*, 1959, (6), 525) Cracks or pits in the mould were the cause.

PRODUCTION OF FERRO-ALLOYS

Evolution of the Japanese ferro-alloy industry (*J. Four Elect.*, 1958, **63**, Nov.–Dec., 210–214) Present output, technical progress, specifications, and the main producers in the Japanese ferro-alloy industry are described, and data tabulated.

Experiments on refining nickeliferous pig iron in the basic electric furnace T. D. Souza Santos (*Bol. ABM*, 1959, **15**, April, 333–344) [In Portuguese] Up to 1957, the Nickel Company of Brazil experienced difficulty in controlling co-reduction and carbon content with the result that the ferro-nickel produced contained about 22% Ni, 2% Si, and 3% C and the author had an opportunity of experimenting with this with a view to reducing the carbon below 1% and the silicon below 0·3%. A 400 kVA, basic-lined Heroult furnace was used; lump and crushed haematite was used for the reduction. Details of each run are given. It is shown that the Si and C can be reduced under these conditions without appreciable loss of Ni and, if required, these elements can be reduced to very low levels (e.g. 0·06% C, 0·04% Si); power consumption was about 752 kWh/t.—P.S.

Aluminothermic ferromanganese F. Dvořák and M. Červinka (*Hutník*, 1958, **8**, (10), 346–352) Production technology and economic aspects of the production of ferromanganese by the exothermic reduction of Mn ores with Al are discussed. Although the method is simple, it is concluded that from the point of view of overall economy electrothermic and electrolytic methods of production are more advantageous, and are likely to be the main methods of Mn production in the future.—F.F.

The thermal balance in the aluminothermic smelting of ferrotitanium S. I. Suchil'nikov and V. V. Melikhov (*Stal'*, 1959, (5), 425–428) A simplified heat balance calculation is given and the main sources of heat loss are identified. A pre-heated shaft and a hot charge are recommended.

FOUNDRY PRACTICE

Progress made in the foundry during the first six months of 1958 P. A. Heller (*Stahl Eisen*, 1959, **79**, Feb. 5, 156–162) A review of the literature published during the first six months of 1958 is given dealing with (*a*) structure and properties; (*b*) melting shop practice; (*c*) moulding and fettling; and (*d*) general (93 refs.).—T.G.

New improvements in the iron foundry C. Tama (*Ing. e Indust.*, 1959, **26**, April, 79–87) [In Spanish] An account of modern technical developments is given with some examples of improvements in Argentine foundries. Modern cupola practice, sand preparation systems, mechanized moulding, and casting and shell moulding are the main themes for discussion.

Crankshafts from nodular cast iron U. Cseh (*Koh. Lapok-Öntöde*, 1959, **10**, Feb.–March, 33–41) Hungarian experiments on the casting of crankshafts from nodular cast iron are described, and the economical, as well as technical advantages of the use of this method, such as improvement of wear resistance, lubrication properties, fatigue limit, damping capacity, and castability of the crankshafts are discussed. For melting nodular cast iron, hot blast cupola, or electric furnaces are the most suitable. Thorough non-destructive testing of the crankshafts is essential.—P.K.

The casting and some material properties of large crank strokes for 'Semi-built-up' crankshafts G. Tschorn (*Giessereitechn.*, 1959, **5**, Jan., 4–9) The technique of moulding, casting, heat-treatment, sampling, and the results of chemical and physical tests are described.

Development of the production of cast iron tractor components in the Třinec steelworks L. Floch (*Slévárinství*, 1959, **7**, (4), 138–140) Recent developments in the production technology and problems relating to minimizing reject rates are considered.—F.F.

Production planning in the foundry branch of industry A. Naundorf and G. Schmidt (*Giessereitechn.*, 1959, **5**, Jan., 1–4) Production planning as applied to East German foundries is discussed in detail.

Planning studies in the foundry R. Sauguet (*Fonderie*, 1958, July, 305–318) After discussing the general principles involved, the author gives a detailed example of the planning of the production of a steel foundry employing 80 persons and making castings ranging from 300 to 2000 kg.

Industrial design for foundry machinery also? W. Klotzer (*Giessereitechn.*, 1959, **5**, April, 107–111) Functional and aesthetic considerations in the design of foundry equipment are studied, with examples.

Classification and specification of foundry equipment A. V. Rumyantsev (*Lit. Proizv.*, 1959, (3), 20–22) An efficient scheme is proposed which prepares the way to automation.

History of the Ganz Iron Foundry in Budapest, Hungary L. Banhegyi (*Koh-Lapok-Öntöde*, 1959, **10**, Feb.–March, 25–33) The author describes the foundation and development of the Ganz Waggon and Engineering Works at Budapest, Hungary, and especially, that of its iron foundry. The main products and production methods of this foundry are also discussed.—P.K.

The control of the cupola F. Kretzschmer (*Giessereitechn.*, 1959, **46**, April 23, 239–240) The importance of controlling the relationships between blast volume and pressure is pointed out, and equipment for the purpose is described.

Brown-coal char as a fuel for foundry cupolas D. G. Evans, R. S. Higgins, and G. L. Kennedy (*Brit. Found.*, 1959, **52**, April, 171–183) Melting trials with Australian hard lump char showed that it behaved similarly to coke except that the metal temperatures were lower with char under the same operating conditions because of its higher reactivity. Increase in lump size or increase in blast velocity are suggested to increase metal temperature.—A.D.H.

Some applications of stress analysis techniques in improving casting designs L. H. Ravitch (*Gen. Motors Eng. J.*, 1958, **5**, Oct.–Nov.–Dec., 22–27) The brittle lacquer and strain gauge methods are described and the application of these techniques to the improvement of product design is discussed and illustrated. A specially equipped test vehicle is used.

Relationship of test bar and casting properties W. J. Reichenecker (*Foundry*, 1959, **87**, Mar., 64–68) Possible differences between the properties of test bars and production castings, the design of test bars and effects of section size and pouring temperature are discussed. The examples given are non-ferrous.

Automated blast cleaning pares labor costs 50% (*Steel*, 1959, **144**, Jan. 19, 74) The installation of automatic sand-blasting equipment for cleaning grey iron castings is reported to have cut labour costs by half.—A.G.

Hot-blast cupola operation: two case histories (*Foundry*, 1959, **87**, Mar., 156) A change-over to water cooling, removing most of the lining so as to increase the diameter from 54 to 62 in., followed by conversion to hot blast is described and cost reductions are given. Another conversion to hot blast of a 44 in. cupola is mentioned and again savings are estimated.

The desirable properties of cupola coke Subcommittee T.S. 47 (*Brit. Found.*, 1959, **52**, Mar., 136–151) A review with a survey of the literature. Testing by mechanical means and cupola trials are considered and the work of the Research Association is noted. Recommendations are added.

Slag handling and disposal 'Jacques' (*Found. Trade J.*, 1959, **106**, Mar. 26, 357–359) Mechanical handling in the disposal of cupola slag is discussed.

Spun pipe water-cooled cupolas K. E. Mathes (*BHP Techn. Rev.*, 1959, **3**, Mar., 20–22) The designs, fitting and advantages of water jackets are described.

Rotary melting furnaces Monometer Manufacturing Co. Ltd (*Auto. Eng.*, 1959, **49**, Feb., 78–80) An illustrated account of these furnaces and their advantages with performance data for the 2-t type are given.

Tilting rotary furnaces Monometer Manufacturing Co. Ltd (*Gas World*, 1959, **149**, Jan. 17, 14) A brief note on standard rotary and tilting rotary melting furnaces.

Comparison of standard and tilting rotary furnaces (*Found. Trade J.*, 1959, **106**, Feb. 19, 211–212) The advantages of the tilting type are briefly noted. The melting efficiency is the same in both.

Industrial electric furnaces J. J. M. Roos (*Engineer Foundryman*, 1958, **24**, Nov., 42–47) The advantages and applications of electric furnaces in the field of heat treatment and metal melting for the secondry industries are discussed.—A.G.

Electric furnaces for metal melting S. G. King (*Engineer Foundryman*, 1958, **24**, Sept., 44–55) The various types of induction, arc and resistance furnaces are described together with conditions of operation and furnace characteristics. Finally the economics of electric melting are briefly considered.—A.G.

The Grey Iron Founder's Society tells designers and buyers why and how to use grey and ductile iron castings R. C. Meloy (*Mod. Castings*, 1959, **35**, Mar. 24–26) The properties of grey and ductile irons are enumerated.

Factors influencing soundness of grey iron castings: A review of some recent British work I. C. H. Hughes, K. E. L. Nicholas, A. G. Fuller and T. J. Szajda (*Mod. Castings*, 1959, **35**, Mar. 73–89) Work carried out by BCIRA during the last few years is reviewed (28 refs).

Effect of carbon, silicon and other factors on the shrinkage behaviour of grey cast iron T. J. Szajda (*BCIRA Res. Dec.*, 1959, **7**, Feb., 567–604) In the work reported carbon was varied to between 2·2 and 4·5%, and Si to between 0·5 and 4·0% in both 0·05% and 1% P irons. Good correlation was obtained between eutectic graphite content and shrinkage and in high P iron, internal porosity.—A.G.

Prize-winning grey iron casting designs (*Western Metalw.*, 1959, **17**, Feb., 21–24) Seven part designs are shown.

The Malleable Founder's Society tells designers and buyers why and how to use malleable iron castings H. J. Heine (*Mod. Castings*, 1959, **35**, Mar., 27–29) The properties of malleable irons are pointed out.—T.G.

The influence of mould rigidity, pouring temperature and metal composition upon the soundness of fed nodular and flake graphite iron castings K. E. L. Nicholas (*BCIRA J. Res. Dev.*, 1959, **7**, Feb., 605–623) The use of a cement sand mould in preference to green sand is said to increase the soundness of both nodular and flake graphite cast irons. The relationships between casting expansion and mould material and pouring temperature have been investigated.—A.G.

Some aspects of spheroidal graphite cast iron production in India with indigenous raw materials S. N. A. Narayan (*Trans. Indian Inst. Met.*, 1959, **12**, Mar., 83–91) A review of materials and equipment.

Growth and scaling in S.G. iron R. J. Maitland and I. C. H. Hughes (*Iron Steel*, 1959, **32**, Jan., 19–24; Feb., 57–59; Mar., 100–103) Microstructures and mechanical test results are described and discussed on growth test bars repeatedly cycled to 900 and 1000°C, and progressively cycled to 1000°C, the Si content of the bars ranging from 1·2 to 5·7%. The results of scaling tests are given. Growth and scaling test data show that provided that exposure occurs below the critical temperature range, growth and scaling in unalloyed cast iron are inhibited by increasing Si content, and growth is much less in nodular than in normal and coarse flake graphite irons. Work reported by various workers is discussed and results are compared. Critical temperature ranges were determined by taking a number of small

samples and heating at various temperatures round the range, subsequently quenching in water and examining the microstructures. The results indicated clearly the rising critical temperature range with increasing Si content, and the approximate width of the range.

Using the sealed ladle W. W. Braidwood (*Eng. Found.*, 1959, **24,** Feb., 38–42) The use of the process in spheroidal graphite iron production is described and directions for melting and adding Mg are given. The properties of the iron are given and typical products are shown.

A note on magnesium nitride as an addition agent for S.G. iron production S. Ramamurthy (*Trans. Indian Inst. Met.*, 1959, **12,** Mar., 92–95) Preliminary work shows that the nitride is effective in producing the structure and also desulphurizes and degasses nonferrous alloys.

Applications of ductile cast iron in the field of pipelines M. C. M. Grandpierre (*Brit. Found.*, 1959, **52,** Feb., 61–65) The development of the use of spheroidal graphite cast iron for pipelines is reviewed, and the manufacture and properties of the pipe, types of joints used, and examples of installations made in France are described.

The Steel Founder's Society of America tells designers and buyers why and how to use steel castings C. W. Briggs and G. K. Dreher (*Mod. Castings*, 1959, **35,** Mar. 30–33) The advantages steel castings offer are enumerated and a table is given of specifications, applications and the physical and mechanical properties of steel castings.—T.G.

General Motors describes Centrasteel W. B. Larson, C. F. Joseph, F. J. Webbere, and R. F. Thomson (*Mod. Castings*, 1959, **35,** Mar., 47–52, 134) Centrasteel is a type of malleable iron, its characteristic is the presence in the as-cast condition of a compacted type of graphite, similar to the temper carbon of malleable iron. Its composition is C 1·70, Si 2·25, Mn 0·10, P 0·05 and B 0·01% nominal. The iron is inoculated with a combination of B and Te or Bi to produce the compacted graphite structure necessary to obtain high mechanical properties. Mechanical strengths in the as-cast and in the heat-treated condition are listed. Castability is said to be slightly inferior to that of malleable iron.—T.G.

Practical guide to the design of cast steel parts Commission technique de la Métallurgie and ASFRAM (*Usine Nouv.*, 1959, Monthly Issue, March, 21, 23, 25, 27–29; April, 63, 65, 67–69, 71, 73; June, 31, 33, 35–37, 39, 41, 43, 44) The properties of cast steel are set out, foundry defects are reviewed and choice of thickness is discussed. Precautions against hot spots are given. Numerous factors in design are then illustrated with reference to concentrated mass, flexibility, size of holes and dimensional precisions. Direction of casting and oriented solidification and other practical features are discussed with numerous examples.

Flowability of moulding sands. I. Relation between displacement in the direction of load and flowability of moulding sands T. Yoshihara and H. Kasai (*Rep. Gov. Ind. Res. Inst. Nagoya*, 1959, **8,** Jan., 38–44) In ramming, change of rammer weight and tube diameter gave a relation between height of specimens and ramming number. A formula for squeezing was also obtained and factors in the expression were related to density distribution and grain breakage. Autoflowability and grain size were also examined.

The specific surface area of foundry sands J. Dlezek (*Slévirenstv.*, 1958, **6,** (8), 243–248) [In Czech] An apparatus for the measurement of the specific surface, i.e. surface area per unit weight, was developed. The equipment can be applied to various powders, particularly to foundry sand. The specific surface is shown to be an index of sand quality of practical importance; for example, it provides an indication of the shape and strength of the particles. The utilization of the concept of specific surface area in problems involving the preparation of synthetic foundry mixtures is discussed.

Properties of moulding materials at high temperature. (VII) Effects of slow heating expansion, hot deformation and hot strength on the scab formation K. Futaki and M. Isotani (*Rep. Gov. Ind. Res. Inst. Nagoya*, 1959, **8,** Jan., 29–37) Scabbing tendency usually decreased with increase of inorganic binders. Wood flour, starch, etc. increased hot deformation and reduced scabbing tendency. Beta-group scab was produced in sand moulds where slow heating expansion exceeded hot deformation and hot strength was below 10 kg/cm² at 800°C. The AFS committee report on scabbing is discussed.

Investigating the strength of ceramic coatings of fused patterns O. V. Stupishina (*Lit. Proizv.*, 1958, (9), 14–17) Experiments are described to investigate the heat-resistant properties and the strength of the rough forms at normal temperatures and the firing of ceramic moulds. Binding materials: a hydrolized solution of ethyl silicate 3, with 14% silica, kept 3–4 days, water-glass with a silicate ratio of 2·8 diluted with water to a sp.gr. approximately 1·22, or the standard binding mixture ARK – No.2 with 14% silica. Moulds prepared with binding mixture ARK-1 have a minimum strength in the raw state, but after firing their strength increases and exceeds that of ethyl silicate.

Influence of technological factors on the strength of coatings in casting with fused patterns M. T. Bogdanov (*Lit. Proizv.*, 1958, (9), 18–20), The coatings were made from the following materials: powdered quartz, dried at 200°, ethyl silicate sp.gr. 0·955 with 30·19% SiO_2 and 0·0093% HCl. Rectified spirit 96°, dusting quartz sand sieved through 30 and 50 mesh and calcined at 800°. The greatest tensile strength was obtained after 16 h drying between 17 and 18° in air. A combined air-ammonia drying gave the same results for strength but the time was reduced to 4·5 to 5 h.

The flow of molten iron through the channels of the gating system J. Szreniawski (*Prz. Odlew.*, 1958, **8,** April, 93–98) The investigations of the flow of molten cast iron through a sand mould are discussed. Pouring heights of 250, 360, 500 and 700 mm and diameters of the gate of 10 and 14 mm were tested. Practical conclusions for the design of gating systems are given.

Study on the gating system for shell mould steel castings M. Dugiyama and K. Kobayashi (*Tokyo Univ. Ann. Rep. Eng. Res. Inst.*, 1958, **17,** Sept., 99–103) Pelline–Cech or Adams–Caine methods are found to be applicable to thirteen castings. For very small steel castings, however, Cech's chart does not apply and conditions for these were worked out.

Investigation of the economics of the use of exothermic feeder head materials in the steel foundry L. Remmeke (*Giesserei*, 1959, **46,** Jan. 15, 34–37) The experimental technique is described, and results evaluated. The data, although based on insufficient trials to be generally valid, show that some economics can be made.

Pouring head for casting with fused moulds I. Z. Shenderovich (*Lit. Proizv.*, 1958, (9), 23) A device is described consisting of an arrangement of moulds in a round collector. This arrangement serves at the same time as a pouring head.

Separating plates for easily adjustable pouring heads A. Ya. Kul'bitskaya, G. S. Dvali, S. F. Fomin, and L. I. Ebralidze (*Lit. Proizv.*, 1958, (9), 24) At the Stalin Metallsrgical works in the Caucasus, these separating plates are made of quartz sand and water-glass and are neither dried nor calcined. The mixture consists of 80% quartz sand type K 50/100, 20% sifted earth and 7% water-glass dens. 1·48–1·50 with a mol. ratio of 2·5–2·6. The gas permeability in the green state amounts to 119–138 units and after drying in air to 163–193 units. Compression strength in the green state, 0·15–0·17 kg/cm², and after drying, 10–15 kg/mm². Humidity in the green state 3–4%.

The formation of seams in large and heavy castings, and the calculation of the pouring rate, taking into account the cooling of the molten metal in the mould Ya. I. Medvedev (*Lit. Proizv.*, 1958, (8), 12–15) Such castings with complicated sections, where the metal must travel a long way, often suffer from short running, seams and incomplete coalescence, if the maximum casting time (maximum time during which the metal will flow satisfactorily) is exceeded. The first fault is due to too rapid cessation of pouring, while the others are due to the too rapid cooling of a section of the casting. These faults are analysed in detail, and the hydraulics and thermodynamics of the process are examined. From the equations derived it is shown that every horizontal section of one and the same casting has its own calculated casting rate, and that the calculation of the requisite rate for the casting as a whole must be based on the rate required by that part of the casting where there is the greatest risk of the formation of the faults outlined, but in practice the rate can be further increased to avoid charring of the mould and surface distortions. The method of calculation has been satisfactorily used in practice. This is the basis of the 'layer' or 'sectional' method of calculating the requisite casting rate.—M. T.

Methods of reducing thermal stresses in cast structures when pouring into green moulds Ya. A. Smolyanitskii (*Lit. Proizv.*, 1958, (8), 16–18) Such thermal stresses increase in proportion to the cooling rate of castings in the mould, and this is dependent on the dimensions of the casting and the pouring rate, and also on the thermophysical properties of the mould materials. It may be shown that the stresses set up in castings in green moulds may be from 20 to 60% greater than those set up in dry moulds, due to the higher thermal conductivity, heat capacity and specific weight of the former. This is most marked where the cross-section of the casting is small, and diminishes with the increase in cross-section. Experiments were carried out on cast iron specimens to test the influence of moisture contents between 3·3 and 6·6% on a thermal coefficient representing the heat exchange between the casting and the mould, and also on the affect of moisture content on the compression strength and gas permeability of the mould, and these two factors were plotted against the thermal coefficient. The plot of the degree of deformation of the casting against this coefficient is also given on the same graph, which indicates what should be done to reduce thermal stresses in castings poured into green moulds and simultaneously to increase the strength and gas permeability of the mould.—M. T.

Subsidiary shrinkage heads for T-shaped junctions in steel castings M. D. Dvorkin and V. I. Rudometkin (*Lit. Proizv.*, 1958, (8), 6–7) The method of calculating the dimensions of, and constructing shrinkage heads illustrated by the example of T-shaped junctions at the periphery of a gear wheel. The graphical method of presentation clearly shows the relationship between the direction in which solidification occurs in such a section of a casting and the dimensions of the shrinkage head, and simplifies preparatory work for making such castings.—M. T.

Casting tears slashed (*Steel*, 1958, **143,** Dec. 1, 74) Improvements in the technique of casting 27 000 lb press platens are described, which almost eliminated the need for repair welding. They involved known techniques, i.e. sand that absorbs expansion; multiple gating of correct thickness; external 1 × 6 in. chills; favourable design; optimum carbon content and temperature of the metal.—D. L. C. P.

Development tendencies in machine moulding in [Eastern] Germany and abroad W. Hofmann (*Giessereitechn.*, 1958, **4,** Dec., 310–316) This is the third of a series of articles dealing with the development of machine moulding, with illustrative examples (*cf. ibid.*, 1958, **4,** (4), 75–78 and (5), 97–102)

Carbon dioxide process for moulds and cores (*Bradley's Mag.*, 1958, Winter, 11) A review.

Ceramic cores J. Hykel and J. Čechura (*Slévárenství*, 1958, **6,** (10), 314–318) [In Czech] The development and practical use of refractory cores made from ethyl silicate, with the addition of ground silica and hydrochloric acid are described. High quality castings with a good surface are produced with such cores, and cleaning and machining costs are reduced.

New core binders – a means of extending the capacity of coremaking shops H. Pfeiffer (*Giessereitechn.*, 1958, **4,** Dec., 323–326) The

results are described and discussed of a series of trials on a new core binder 202 GSI.

Economic advantages of chamotte mouldings J. Glogier (*Prz. Odlew.*, 1958, **8,** (1), 19–22) The cost of moulding in chamotte is 3 to 5 times that of moulding in sand and the time of preparation of the moulds is 15–20% longer. To obtain high-quality castings it is sometimes to be recommended nevertheless.

Hydrolysis of ethyl silicate in precision casting M. V. Sladkova (*Lit. Proizv*, 1958, (9), 8–12) The hydrolysis products depend on the amount of water available, according as it amounts to less, equals or exceeds the stoichiometric quantity. In the USSR one-stage hydrolysis is preferred to multi-stage. Water does not mix with ethyl silicate, hydrolysis can therefore only occur at the interface and proceeds very slowly. Solvents used in the USSR both for water and silicate are: rectified ethyl alcohol, acetone or ester-aldehyde fraction (EAF). The adhesive properties are determined by the nature and the amount of solvent used, by the stages of hydrolysis and by the preparation of the surface of the model.—L. R.

Two methods of ethyl silicate hydrolysis Ya. I. Shklennik (*Lit. Proizv.*, 1958, (9), 12–14) The raw materials for the tests consisted of ethyl silicate 32·23% SiO_2; 0·058% HCl; dens. 0·965; 100% fractions with b.p. above 110°. Rectified spirit 95°, hydrochloric acid dens. 1·185; distilled water; powdered quartz; sand. A description is supplied of the one and two-stage processes and of reasons why the single stage is preferred.—L. R.

Cast specimens for the control of mechanical properties of precision castings N. M. Tuchkevich and V. S. Petrova (*Lit. Proizv.*, 1958, (9), 20–21) Instead of the clover-leaf or the wedge-like shape of control specimens, a non-standard form of control for castings is suggested which ensures a directed solidification during crystallization and a compact structure at the place of fracture of the specimen.

Continuous casting of steel wheels for mine cars J. Wojto'w (*Prz. Odlew.*, 1958, **8,** May, 135–141) The development of the continuous casting process in the USSR is briefly surveyed. Various technical problems connected with the mechanization of the production of the wheels in Poland are discussed.

Production of a large steel casting F. J. Drake (*BHP Techn. Bull.*, 1958, **2,** Sept., 21–25) Details are given of the moulding, casting and dressing of a 54½-t casting in 35-t tensile steel.

The centrispinning process as applied to the manufacture of high-duty components in high-alloy steels A. E. Thornton (*Brit. Found.*, 1958, **51,** Nov., 559–569) An outline of the development of the centrispinning process is followed by a description, illustrated by examples, of the type of work produced, operating details, defects found, acceptance standards and system of inspection, in the production of parts for aero engines.

The economics of precision casting R. G. Nicholas (*Brit. Found.*, 1958, **51,** Nov., 541–548) The effects of the major factors influencing the manufacturing costs of various precision casting processes are assessed and compared.

The precision casting process with lost mercury models H. Allendorf (*Giesserei-Techn.*, 1959, **5,** March, 78–81) A description is given of the properties of solid mercury as a material for models, and of the mercury process. Its advantages over the wax casting process are stressed.—L. J. L.

The importance of the temperature distribution in castings on cooling F. Havlíček (*Slévárenství*, 1958, **6,** (9), 283–286) [In Czech] The dependence of internal stresses in castings on the shape and size of the castings are discussed. From the point of view of avoidance of surface tears, oval or rectangular shapes are preferable to cylindrical ones.—P. F.

Increasing precision in shell moulding by the use of filler mould-supports S. Šimonik (*Slévárenství*, 1958, **6,** (8), 254–255) [In Czech] It is shown that a higher precision is attainable, and thicker castings can be cast, if shell moulds are supported by a bed of filler material. Sand was found unsuitable as filler, but cast-iron shot or gravel yielded good results. Vibrating the mould in the filler bed was found to be advantageous, giving the mould greater rigidity. Gravel fillers are likely to be most suitable in practice, as these would require a minimum of alteration to existing procedure.—P. F.

Technological conception of shell moulding H. Rapacki (*Prz. Odlew.*, 1958, **8,** April, 98–106) Rules for the design of castings suitable for shell moulding are given. Due to the dimensional accuracy of surface smoothness, the allowances for machining can be substantially reduced or completely eliminated. Different types of gating systems for shell moulding are discussed.

The influence of magnesium on cast iron shrinkage L. Sofroni, R. P. Todorov, and G. I. Kosovnik (*Studii si Cercetari de Metalurgie*, 1958, (3), 295–305) [In Rumanian] Tests were carried out on grey cast iron and on Ni-C; Ni–C–S; Fe–C; Fe–C–S; and Co-C alloys for comparison purposes. Findings show that the volume of shrinkage is determined by the graphite which segregates during eutectic transformation, whilst the initial swelling is due to graphite segregation at sub-eutectic temperatures. Magnesium increases the initial dilatation and the subsequent shrinkage owing to an increase in the sub-eutectic and a reduction in the eutectic graphite during solidification. This can be explained by an increase in the degree of under-cooling during eutectic transformation and by the decomposition of cementite at sub-eutectic temperatures.

The influence of the temperature of liquid iron on the depth of the chill in wedge-shaped specimens I. E. Brainin and S. I. Shapovalov (*Lit. Proizv.*, 1958, (12), 19–20) The chemical composition of the material investigated fluctuated between 3·6–3·9% C; 1·4–1·7% Si; 0·5–0·8% Mn; 0·06–0·12% P; 0·05–0·10% S. The iron was poured into three wedge-shaped moulds at a time. The depth of chill of the first castings was always smaller than that of the third. All third castings to the number of 151 were divided by the temperature of casting into three groups and the constant of graphitization for each specimen calculated according to the formula $K_g = C[Si - 0{\cdot}2(Mn - 3{\cdot}38) + 0{\cdot}1\,P]$, where the symbols represent the percentage contents of the respective elements. The findings, proving a reduction in the depth of chill with increasing temperatures of the iron in the runners, contradict the data given in the literature. Explanations based on tabulated results are offered.

On the causes of the formation of cracks in tubing steels A. S. Babin, D. I. Sapiro, S. I. Zhmak, and G. E. Kravtsov (*Stal'*, 1958, *Steel melting processes supplement*, 115–126) Cracks and holes accompanying blisters are the main causes of rejects. These are caused mainly because the rate at which the metal fills the mould does not correspond to its temperature. Investigations have established optimum conditions for making tubing steels; temperature of metal at pouring should be 1510–1520° by pyrometer reading in the runners; duration of metal boil no longer than 50 min; no molten pig iron additions during melting, and a pouring rate of 0·15–0·20 m/min.—L. R.

Molybdenum in alloy steel castings G. French and B. H. C. Waters (*Alloy Met. Rev.*, 1959, **9,** Mar., 2–11) Steelmaking practice using Mo is outlined and the effects on hardness, creep and high temperature properties in low alloy steels and in austenitic 18–8 and tool steels are given. The properties of typical alloys are given and structures are shown. Heat-treatment is outlined.

The Alloy Casting Institute tells designers and buyers why and how to use high-alloy castings E. A. Schoefer (*Mod. Castings*, 1959, **35,** March, 34–35, 134) The properties, composition and useful applications of straight Cr, Cr–Ni, and Ni–Cr steels and alloys are discussed.—T.G.

Sand preparation (*Eng. Found.*, 1959, **24,** Mar., 39–40) An account of the 'Pneulec' plant recently installed in the Transvaal with a throughput of 3 t/h and a batch size of 6 cwt.

Compaction of sand J. F. Kayser (*Found. Trade J.*, 1959, **106,** Jan. 29, 121–123) The close packing of spheres as an approximation to the compaction of foundry sand is questioned. Microscopical observations show that the particle distribution is random and various previous suggestions are noted. The phenomenon of dilatancy is referred to and the increase of voids resulting from shear. The permeability may therefore be increased by higher compression.

Sand movement and compaction in green sand moulding T. J. Bosworth, R. W. Heine, J. J. Parker, E. H. King and J. S. Schumacher (*Mod. Castings*, 1959, **34,** Jan., 93–101) The principles controlling sand movement during squeezing, jolting and contour squeezing are discussed. The compaction process and the development of the mechanical properties with increasing density are described. Rigid frame design rules for contour squeezing are given, with methods of using the contour frame to achieve moulds of high and uniform density and hardness.—T.G.

How to keep green sand quality control on the beam A. Johnson (*Mod. Castings*, 1959, **34,** Feb., 34–36) The physical properties of a sand depend on the relation between moisture and clay content. High-strength sands tend to improve the casting finish and require less combustibles. Changes in density can be observed when a sample is weighed for a green compression test.—T.G.

Tempering moulding sand H. W. Dietert, V. Rowell and A. L. Graham (*Mod. Castings*, 1959, **34,** Feb., 55–61) Test procedures for actual and compensated moisture tests are described. A method of determining the riddled density of sand is given and its relationship to % moisture shown. Ultimate deformation is proposed as a new method of controlling the sand temper in place of using % moisture as the index for Western bentonite, clay and natural bonded sand.—T.G.

Non-ferrous foundry uses sand and metal moulds R. H. Herrmann (*Foundry*, 1959, **87,** Feb., 94–97) For the pressure die casting of Zn, hardened tool steel dies are employed.

Flowability of moulding sands. II. Kyle's flowability and Lissel's flowability T. Yoshihara and H. Kasai (*Rep. Govt. Ind. Res. Inst. Nagoya*, 1959, **8,** Mar., 196–200) The hardness of the green mould is related to the former. Replacement of hardness by compression stress gives a ratio probably related to lubricability. The latter is affected by weight of sample and increases with dry bulk density. The relative error is small but the measurement is time-consuming.

Measurement and control of moisture content in moulding sands P. Lippke (*Found. Trade J.*, 1959, **106,** Jan. 15, 61–64) A review of principles and methods for chemical, conductimetric and dielectric measurement and a discussion of types of instruments and their use.

The pH of foundry sands W. B. Parkes (*BCIRA Bull.*, 1959, **14,** Jan., 644–647) A review of measurement, control and effects.

Gating, running and feeding (*Bradley's Mag.*, 1959, Spring, 6–7) An account is given of iron shrinkage on solidification, feeder head design, and points on gating and running.

Dimensioning of sand casting risers H. D. Merchant (*Mod. Castings*, 1959, **34,** Feb., 73–85) An analytical method is formulated to determine size and shape of risers. It may be used for any metal or alloy under certain restrictions and assumptions. It does not answer the questions of how many and where, but it does answer the questions of what diameter and how high (24 refs.).—T.G.

Feeding castings under pressure S. T. Jazwinski (*Arch. Hutn.*, 1959, **14,** (1), 45–62) Linseed oil was used as gas-producing agent, mixed with sand, clay and exothermic powder and introduced into the feeder in a special refractory container which controlled the delay before action by the thickness of the lid. A method of determining the rate of metal solidification and its advantages in measuring skin formation in steel castings are described, and an equation giving approximately the thickness of metal as a function of time is obtained. A special refractory valve preventing blow-back is illustrated. Higher metal yields and sound castings were obtained.

Foundry clays J. J. Marais (*Brit. Found.*, 1959, **52,** Jan., 4–7, discussion 8–9; *Engineer*

Foundryman, 1959, **24**, Jan., 37–42) A review of the three main types, their identification, their properties in relation to the foundry and their uses. Some misconceptions are also noted.

Ball clays (*Iron Steel*, 1959, **32**, Feb., 55–56) The structure of Dorset ball clays and their suitability for foundry use are described, in the light of research carried out by Pike Bros., Fayle & Co. Ltd.

Do you ask 'Which core process?' W. B. Bishop (*Can. Metalw.*, 1959, **22**, Feb., 22–26) The author describes the four main foundry core-producing processes, namely, the conventional process, the shell or hollow core, the gas-setting core, and the air-setting core. The advantages and disadvantages of each type are discussed, and their potential fields of greatest application are considered.—G.F.

Developments in the use of the carbon dioxide process W. Schumacher (*Foundry*, 1959, **87**, Mar., 69–75) Heavy-walled castings were examined and deformation of the cores was observed. A test specimen was devised with wall thicknesses between 40–100 mm with re-entrant angles at the acute angle between two sides. A variety of sands and a silicate binder with a 2·5 ratio and 10% sugar solution were used. Findings are tabulated and thermal analysis curves were determined for some of the mixtures. Evaporation of some of the water by heating before gassing was advantageous, or CO_2 at 35°C could be used. Quartz sand was not found to be very suitable.

The production of investment castings for commercial applications P.I. Castings (Altringham) Ltd. (*Machinery*, 1959, **94**, Mar. 4, 484–492) An illustrated description of a plant producing ~10 cwt/week, 95% of steel.

Investment casting in U.S. and U.K. (*Found. Trade J.*, 1959, **106**, Feb. 19, 203–209). **American investment-casting activities** H. P. Gray. The state of trade, the history and work of the Investment Casting Institute and the use of the Shaw, Glascast and Investment 'X' processes are briefly reviewed. **Developments in investment precision casting** A. Dunlop. An account of the original Austen process with notes on the investment 'X', Mercast, Glascast and Shaw processes is given.

Miniature investment castings (*Prec. Met. Mold.*, 1959, **17**, Mar., 33–35) This article illustrates many of the miniature parts produced by investment casting at the works of Precision Metalsmiths Inc. Brief details are given of the metals cast, the tolerances achieved, and cost savings.—G.F.

Machine for pipe spinning (*Engineer Foundryman*, 1958, **24**, Dec., 46) The machine described consists of an alloy steel mould rotated in a water jacket and able to travel along an inclined set of rails. Operating procedure is given.—A.G.

Centrifugal casting applied to grey iron L. M. Intosh (*Castings*, 1959, **5**, Jan., 7, 9, 11, 13, 15, 17) Machines are described in general terms, mould speeds are discussed and the metallurgy of the process is briefly reviewed.

Additional spun-pipe capacity for India (*Found. Trade J.*, 1959, **106**, Jan. 22, 89–95) The Kulti installations with a rated capacity of 7500 t/month on a 2-shift basis making 9–27 in. dia. pipes is described. The production is to be raised to 20,000 t/month. After an illustrated account, a list of the principal contributing firms in this country and in India is given.

A new type of core binder for high-frequency drying W. W. Magers (*Giesserei*, 1959, **46**, April 9, 191–192) An account is given of the properties and performance of a new synthetic binder 'Diresan'. The binder is suitable for dielectric drying, and has strength values equal to the best core oils. It works well, sand mixtures have good flow properties, and good cores are produced with high bend strengths.

Mathematical analysis of the processes taking place in the mould and core blowing machine P. N. Aksionov (*Gjuteriet*, 1959, **49**, (3), 65–66, 69–70, 73–75; *Prz. Odlew.*, 1959, **9**, (3), 61–66) The thermodynamic changes taking place in a core blower are analysed, and a method for calculating air consumption is outlined. Both exact and approximate methods are shown.

High-strength chains cast in steel M. Flour (*Fonderie*, 1958, July, 297–301) An account is given of the manufacture of steel sand-cast chains, with some of their applications.

Iron castings in the chemical industry G. A. J. Begg (*Brit. Found.*, 1959, **52**, April, 183–193) The application and design of castings, especially of Ni–Fe for corrosion-resisting plant, are discussed.

Dimensional accuracy of castings P. P. Berg (*Prz. Odlew.*, 1959, **9**, (3), 67–70) In this translated article it is shown that the dimensional accuracy of castings is not laid down with the same accuracy as that for machining. Consideration is given to suitable standards of dimensional accuracy for castings, and the occurrence of accidental and systematic errors, and a formula is derived for calculation of permissible dimensional tolerances. The numerical values of the empirical factors representing casting technique, pattern production technique, and casting equipment were calculated on the basis of practical data.—M.T.

Shell moulding at Csepel, Hungary O. Rácz and L. Kálmán (*Koh. Lapok-Öntöde*, 1959, **10**, Feb.–March, 84–89) The authors describe the materials and techniques of shell moulding in Csepel, Hungary. This method is used there for the production of cylinders and chain links of motor cycles.—P.K.

How to make shell moulding pay (*Iron Age*, 1959, **183**, Feb. 5, 96–98) Experience at a plant which compared the green sand and shell moulding methods are described. The extra cost of shell moulds was recovered in many cases by subsequent savings.—D.L.C.F.

Solidification of various metals in ingot and sand molds W. S. Pellini (*AIMME Proc. O.H. Comm.*, 1958, **41**, 93–135) The past six-years' thermal-analysis studies at the Naval Research Laboratory are summarized into a concise presentation of the mechanism of solidification of metals as related to metal and mould variables. Particular attention is given to the development of an integrated concept of the mechanism of solidification of various metals, and the studies relating to steel, grey and nodular irons, and non-ferrous metals and stainless steel are considered separately. The solidification and feeding of simple shapes are considered, and finally the relationships of solidification features to foundry characteristics are discussed.—G.F.

The penetration of metal into sand cores K. Fursund (*Giesserei*, 1959, **46**, March 26, 159–164) In order to determine the causes of steel penetration into moulding sand when pouring heavy castings at low casting temperatures, a testing method has been developed for the simultaneous measurement of various core sand mixtures and different metal pressures. The effects of temperature, sand grain size, metal pressure, and sand additives are discussed, and the author develops a theory of the change in depth of penetration with pressure.

When, where and why [do defects] occur in a natural sand mould U. Harada, K. Nishiyama, and T. Kubota (*Imono*, 1959, **31**, March, 186–193) [In Japanese] Scab is caused by the expansion of foundry sand on the mould surface and the load breaking up the surface. Scab and rat-tails occur as long as internal stress is concentrated on the mould surface. Scab forms more easily with higher humidity and temp., and is associated with sand permeability.—K.E.J.

Where do pinholes come from? S. A. Sanders (*Fonderie*, 1958, Feb., 53–63) Various factors contributing, or possible causes of, the formation of pinholes in different types of cast iron and steel are discussed. It is concluded that the most probable cause of pinholes in steel castings is the formation of CO, produced by the interaction of C and FeO at the mould/metal interface (19 refs.).

The industrial utilisation of knowledge relating to the formation of internal tears in large castings S. Burda and M. Bakala (*Hutn. Listy*, 1958, **13**, (9), 786–795) The literature on the subject is critically surveyed, and the origin and prevention of cracks are considered. Detection by ultrasonics is recommended, and welding up of the cracks present by thorough forging is shown to ensure high quality forgings meeting the specifications for rotors and other parts of heavy machinery.—P.F.

Steel defects in large, mechanically forged crankshafts for piston engines H. Schumann (*Neue Hütte*, 1959, **4**, April, 218–231) Various types of internal defects and their causes in a number of scrap forged crankshafts were investigated, and the suitability of ultrasonic testing as an acceptance test is discussed (24 refs.).

The measurement and control of dust in foundries A. H. Sully, C. M. Stoch, and J. M. Slater (*Brit. Found.*, 1959, **52**, April, 193–211) Methods of sampling steel foundry dust and the results of a survey of 58 fettling shops are given. The free silica content of such atmospheres is much lower than previously thought. Methods of dust suppression and control are reviewed.—A.D.H.

VACUUM METALLURGY

Vacuum metallurgy in Europe A. M. Aksov (*Met. Prog.*, 1959, **75**, Feb., 87–89) Recent European progress in vacuum metallurgy is reviewed under the headings: vacuum induction melting, vacuum arc melting, vacuum degassing, and vacuum heat-treatment.—T.G.

Vacuum as a furnace 'atmosphere' L. W. Johnson (*Met. Prog.*, 1959, **75**, Feb., 71–73) The advantages of a vacuum as furnace 'atmosphere' are listed together with the disadvantages, and vacuum pumps and furnace types are briefly discussed.—T.G.

Vacuum melting and treatment of metals (*Stal'*, 1959, (3), 238–241) A review of US practice from recent publications.

Production of Armco iron from 08–10 rimming steel by vacuum treatment of the liquid metal in the ladle N. P. Zhetvin (*Stal'*, 1959, (5), 419) Vacuum treatment in the ladle is used to reduce C content to 0·03–0·025%, the metal remaining hot enough for teeming. The pressure was reduced to 5–10 mm by the installation of new pumps.

Vacuum casting of steel Z. Motloch (*Hutn. Listy*, 1958, **13**, (11), 1037–1050) Laboratory and pilot plant experiments on the vacuum casting of plain and alloy steels into ingots of up to 2·5-t are described. The effect of casting conditions, particularly the level of the pressure in the vacuum system on the evolution of H_2 is considered. The macrostructure and mechanical properties were studied. Vacuum-cast rimming steels have a structure indistinguishable from that of killed steels. Formation of hair-line cracks, N_2 contents of vacuum-cast steels, as well as the design of the equipment are discussed.—P.F.

The effect of vacuum treatment on ingot quality V. F. Isupov (*Stal'*, 1959, (6), 525) A note from the Serov Combine. Pressures of 30–300 mm in the mould during bottom pouring did not reduce the number of inclusions, bonded structures on the edges, blisters below the crust, and some segregation resulted. Mechanical properties were mostly unchanged but the impact strength of 35 KhGSA steel was reduced.

Application of vacuum casting to the manufacture of steel L. Gascuel (*PACT*, 1959, **13**, Feb., 63–64) Advantages of vacuum casting in producing high-purity steel free from non-metallic inclusions are outlined.

Effect of melting practice on the properties of stainless steel R. S. Belyakov (*Primeneniye Vakuuma v. Metallurgii*, 1958, 35–38; *HB*–4363, from *Techn. Translations*, 1959, **1**, April 3, 233) Production of 18–8 steel in vacuum induction furnaces for the lowest possible C content was examined and steels poured at 2–7 mm and in air were compared.

Pilot-plant experiments with vacuum casting of a low-alloy Cr–Ni–Mo steel Z. Motloch and A. Kalivoda (*Hutnik*, 1958, **8**, (12), 396–399) Experiments on vacuum casting of 2·5-t ingots are described. The H_2 content and the content of (Fe, Mn) S inclusions are significantly reduced by vacuum casting; the ductility, and notch-impact strength are increased, while the yield-point and strength decrease slightly.—P.F.

Heating problems in the large-scale degassing of steel melts H. Knüppel, K. Brotzmann, K. Rüttiger, and A. Diener (*Stahl Eisen*, 1959, **79**, March 5, 272–276) The vacuum-treatment of steel melts requires time

and is enhanced by a large surface, both promote heat losses that can be made up only by additional heating. The authors discuss the sources and the degree of heat loss and report experiments on the heating of industrial steel melts by resistance and arc heating. The experiments show that arc heating is to be preferred.—T.G.

Principles of industrial, large-scale degassing of steel for rolling and forging by the vacuum siphon process F. Harders, H. Knuppel, and K. Brotzmann (*Stahl Eisen*, 1959, **79,** March 5, 267–272) The vacuum siphon process for the degassing of large-scale batches of steel is described. The principle is to lift part of the steel melt from the ladle into the degassing vessel, and to re-discharge it after the vacuum-treatment. This is repeated until the whole charge in the ladle shows the required degree of degassing. Details of the process, its laws, the heat losses and temperature drop as well as the additional heating needed and the results obtained in large-scale operation are reported.—T.G.

Evolution of gas from materials in a vacuum R. Jaeckel and J. Schittko (*Forsch. Wrts. Nordrhein-Westfalen*, 1957, (369), pp. 35) A method is described, simulating conditions in full-scale operation, for the measurement of gas losses of materials under a vacuum of $5 \cdot 10^{-4}$ to 10^{-4} mm. The materials tested were mainly plastics and non-ferrous metals, but some ferrous examples are given.

Investigating the technology of producing hot rolled transformer steel with specific losses of 0·8 watt/kg N. F. Dubrov (*Stal'*, 1959, (6), 566) A note from the Ural Research Institute for Ferrous Metals. Reduction of S, Ni, Al_2O_3, and Ti and treatment in vacuum furnaces, or vacuum treatment of the liquid steel gave the necessary properties.

REHEATING FURNACES AND SOAKING PITS

[**Soaking pits at Dzerzhinsk**] A. D. Kutsenko (*Stal'*, 1959, (6), 573) An improved air injection system is described.

Automatic temperature control of soaking pits in the Třinec steelworks E. Smilowski and O. Obdržálek (*Hutnik*, 1959, **9,** (4), 132–137) Various methods of temperature control in current use in Czechoslovak soaking pits are discussed. Programming of blast-furnace and coke-oven gas input is considered to be most economical.—P.F.

Study of the operation of soaking pits of mill 825 with a view to improving their efficiency I. P. Zabaluev (*Stal'*, 1959, (5), 467) A brief note. Measures improving throughput by 10–12% are mentioned.

Electric soaking-pit practice at Appleby-Frodingham using controlled-cooling methods P. Charlesworth (*JISI*, 1959, **193,** Dec., 368–372) [This issue].

Improving the heating of blanks in continuous furnaces V. F. Isupov (*Stal'*, 1959, (6), 573) A note from the Serov Combine. Changes required on substituting lignite gas in a section rolling mill furnace are noted.

The influence of the heating time of blanks on the quality of tubes N. L. Oslon, A. Z. Gleiberg, and R. I. Chemerinskaya (*Stal'* 1955, (6), 537–540) The heating of the blanks before rolling must be carried out in the least possible time compatible with normal practice. An increased rate of heating reduces the number of internal flaws whilst the outer surface of the tubes does not deteriorate. The slipping during the piercing operation is also reduced due to the reduction of the internal defects

Operating experience with a controlled pusher-type furnace W. Ohnrich (*Neue Hütte*, 1959, **4,** April, 238–243)) The economic use of measuring and control equipment of a billet pusher-type reheating furnace is investigated. The equipment is described and the results discussed.

Automation and mechanisation of gas fired pusher furnaces B. Kolarz (*Hutnik*, 1958, **8,** (10), 337–340) The equipment of ingot reheating furnaces with automatic control of the heat supply, and the introduction of recuperators in the case of furnaces undergoing reconstruction is recommended.—P.F.

Some problems in the construction and running of pusher furnaces B. Kolarz (*Hutnik*, 1958, **8,** (12), 411–413) Modern pusher furnaces are discussed, and certain aspects of the construction, e.g. the effect of burner disposition on the pressure distribution in the furnace and on the air uptake, the thermal insulation of the rails, and the advisability of using side burners are considered.—P.F.

Molten slag removal from soaking pits V. K. Yatsura (*Stal'*, 1959, (6), 522) Two oil-fired pits were converted to molten slag removal with a burner to heat the slag taphole. Addition of 4 vols coke breeze and 1 vol sand reduced the m.p. of the welding slag to 1250–1300°C and the slag was removed continuously.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Definitions of heat-treatment terms (*Ing. e Indust.*, 1959, **26,** April, 95–96) [In Spanish] An alphabetic list of 36 terms used in the heat-treatment of steel, with brief explanations of each term, is given.—P.S.

Industrial furnace technique H. Boenecke (*BWK*, 1959, **11,** April 5, 189–191) A review of literature published in 1958, relating to developments in the design, operation, and control of industrial furnaces (54 refs.).

Industrial electric furnaces and electric heating equipment F. Gerlach (*Elektrowärme*, 1959, **17,** April, 116–129) Modern types of electric arc and induction furnaces, and special-purpose equipment for heat-treatment, spark erosion etc. are described with illustrations, and with reference to the manufacturers.

Foundations for industrial furnaces V. Balabánov (*Hutn. Listy*, 1958, **13,** (11), 984–987) The choice of materials for the foundations as determined by the temperature and temperature distribution is considered. The temperature distribution in various furnace foundations is discussed; the relevant formulae are given and illustrated by means of examples.—P.F.

Heat insulation of pipes in the hearths of continuous furnaces I. P. Bol'shakov (*Stal'*, 1959, (5), 465–467) A system of surrounding the pipes with prefabricated fireclay blocks is described. It reduces heat losses from the cooling water by a factor of 4–6 in gas heated furnaces with a temperature under the metal of not over 1375°C. Installation takes 5–8 h and consumption is 2–3 t per furnace per year.

Protective atmospheres G. Kluge (*Tek. Tidsk.*, 1959, **89,** March 13, 245–250) Various types of protective gases, their action, and their uses in the metal, chemical, and petroleum industries are described.

Inert gases for controlled-atmosphere processes E. F. Gorman (*Weld. J.*, 1958, **37,** Sept., 882–889) The use of A or He for controlled atmospheres is discussed and the degree of purity to be expected in commercial supplies indicated. It is shown that effective use of these gases depends on efficient purging of the chambers or furnaces.

Protective atmosphere gases produced from industrial nitrogen for the heat treatment of steel L. V. Beloruchev and A. K. Shvachkin (*Stal'*, 1959, (4), 354–360) Industrial N_2 from O_2 plants can be purified by heating with charcoal or with dissociated NH_3. A generator is described.

Functional plant layout increases commercial heat treating productivity J. D. Renollet (*Ind. Heat.*, 1959, **26,** Jan., 198–204, 192) The Franklin Steel Treating Co. installation is described.

Development of heat treatment conditions for sheets in roller furnaces and increasing roller life N. P. Khetvin (*Stal'*, 1959, (5), 460) A note on research at the Hammer & Sickle works. Centrifugally cast Kh25N2082 rollers have been tried successfully and three other experimental designs have been developed. **Development of heat treatment conditions for Kh18 steel rod and wire** (460) Brittleness developed on ageing. Pickling and tempering conditions to avoid this are indicated. **Investigation of the decarburization kinetics of tool and ball-bearing steel during heat treatment** (460) Effects of various laboratory heating conditions on carbon level at 0·2, 0·4, and 0·6 mm below the surface were studied. The protective effect of scale was confirmed.

Lecture on gas carburizing F. W. Haywood (*Härt. Techn. Mitt.*, **11,** (2), 38–53) The author deals with the following subjects: separate and furnace-generated atmospheres and furnace equipment; results obtained by the use of prepared town's gas and the Wild-Barfield 'Carbodrip' process and carbonitriding.

Dew point monitoring pays off A. R. Keefe and M. R. Koehn (*Steel*, 1958, **143,** Oct. 13, 100–101) Two multipoint Surface Auto-carb dew point recorders have been installed to measure the dew point in five endothermic gas generators and in the six carburizing furnaces which they serve. The benefits of this system in conjunction with other methods of quality control are cited.—A. G.

Induction heating of internal cylindrical surfaces in metals A. V. Donskoi and B. F. Nadtochy (*Elektrichestvo*, 1958, (6), 25–29) This method of heating the internal surfaces of various metal parts for tempering, hardening or plating has been inadequately studied. Of prime importance is the extent and nature of the distribution of the electromagnetic energy absorbed by the heated metal. This can be analytically resolved by approximate assessment of the skin effect in wave guides, and in this article formulae are deduced for such calculation. Hence the equivalent electrical parameters for the inductor metal electromagnetic system can be calculated. The results of experimental verification of the formulae deduced show that the method of calculation affords sufficient accuracy for practical purposes.—M. T.

Cast high alloy heat treating fixture of unusual design withstands severe thermal shock and carburizing gas corrosion E. A. Schoefer (*Ind. Heat.*, 1958, **25,** Oct., 2017–2024) A solution to the problem of heat treating large numbers of car steering cams is described. A high-alloy cast fixture of articulated design successfully withstands the gas atmosphere, abrupt changes in temperature and heavy loads.—A. G.

Study on continuous gas carburizing A. Tsutsui and M. Ichihara (*Nippon Kinzoku*, 1958, **22,** July, 337–341) The effects of continuous gas carburizing on toughness and structure have been studied and results are reported.—A. G.

A study to improve the heat treatment of cemented steel 20Kh2N4 Syu Tsya-Da (*Acta Met. Sin.*, 1958, **3,** (2), 129–137) After cementation the hardened layer contains a large quantity of residual austenite which still persists after renewed hardening at ~ 800°, giving low hardness and low fatigue limit. A. N. Zhironkin proposed tempering at 640–670° for 3–8 h and this is being done at present. This article describes an investigation into the process of the structure transformation and proposes to use the characteristics of residual austenite decay according to curve C, and to carry out the tempering at its maximum point (for steel 20Kh2N4 at 600° and keeping at that temperature for 1–1·5 h). This method has given good results.

Dilatometric investigation of physico-chemical phenomena in sulphiding T. P. Gil'man (*Metallov. Obra. Met.*, 1958, (10), 33–36) Iron sulphides form when iron powder is sintered with sulphur at 200–300°. Sulphide anti-scoring skins may be produced in hardened specimens on tempering at 180–200°.—L. H.

Interaction of some salts used for sulphiding with cast iron and steel A. V. Kriulin (*Metallov. Obra. Met.*, 1958, (10), 58–62) Curves were plotted for a range of salts used for sulphiding, mixed with cast iron and steel chips. Thiocyanates of Na and K were found to react most strongly with iron. Ammonium thiocyanate, sodium sulphide, sodium sulphite, sodium bisulphite and thiourea also reacted with iron. Lead thiocyanate, iron sulphide, sodium sulphate and sodium thiosulphate did not react.—L. H.

Contribution to the study of the 'sulfinuz' treatment R. B. Wilhelm (*Met. Elect.*, 1959, **23,** Jan., 168–184) The sulfinuz surface treatment is outlined, a number of experiments are described in which the effect of the treatment on the properties of the treated steels was

investigated, and the mechanism of the treatment is examined.

Sulphiding of high-speed steels Suy Tsu-O, Su Po-Yun, Den Yu-Lye, and Lyan Zin-Men (*Chinese J. Mech. Eng.*, **6**, (3), 176–185) Specimens of steel R9 were investigated. The FeS forming during sulphiding segregates mainly along grain boundaries if sulphiding is carried out on hardened steel, but if it is first tempered or cold-worked before sulphiding, the FeS is segregated within the grains. The depth of the sulphided layer is considerably greater on specimens first cold-worked before sulphiding than on specimens first tempered and then sulphided. The sulphided skin is not deeper than 0·1 mm. The relation between depth of sulphided skin and duration of the operation does not show a parabolic relation. Sulphiding has little influence on hardness or red-hardness of high-speed steels and only increases the surface hardness. Sulphided specimens have a greatest resistance to wear, and specimens first cold-worked a considerably greater resistance. Treatment recommended for steel quality R9: quenching from 1240°, cold-working and sulphiding for 1 h at 560°.

Bright Hardening of steel A. K. Beskrovnyi (*Metallov. Obra. Met.*, 1958, (10), 56–57) Conditions are given for bright hardening (hardening combined with electrolytic polishing) of 0·25%C, 0·7%C and 1·2%C steels using an electrolyte consisting of 88%H_3PO_4 + 12% CrO_3. The part is suspended from a copper busbar between two lead cathodes. The susceptibility of the steels to cracking is less pronounced than in conventional quenching.

Surface hardening of cutting tools with electric sparks V. Radetchi (*Met. Constr. Masini*, 1958, (9), 693–696) [In Rumanian] At the point of the electric discharge an electrothermal process develops with temperatures of *ca* 10000° which causes modifications of the metal surface, such as by diffusion of carbon and nitrogen. The temperature falls rapidly towards the interior, so that the thickness of the heated layer varies between 15 and 100 microns. If a condenser is mounted in the circuit in parallel with the discharging contacts, the arc will disappear for certain values of the capacity, thus all the energy of the circuit will be accumulated in the condenser. Results obtained by applying this principle have shown great advantages with such tools as drills, milling cutters, disc cutters, etc. Details of various discharge schemes are given.—L. H.

New method of peripheral surface hardening of gear wheels of average modulus K. Z. Shepelyakovskii and R. I. Entin (*Vestnik Mashin.*, 1958, (12), 53–58) Experiments are described on the surface-hardening of gear wheels of average modulus by continuous induction heating up to the hardening temperature, eliminating the need for powerful induction heaters, and by hardening agents and methods resulting in a rate of cooling exceeding the critical rate. This method makes it possible to use steels of considerably lower hardenability. The findings of these experiments are considered so important that the editor has appealed to specialists to examine the facts at once and report.

An apparatus for hardening the teeth of saws for the hot cutting of metal V. V. Tatarnikov, A. N. Zannes, and E. P. Rybaev (*Metallurg*, 1958, (8), 28) A reduction transformer with a primary winding voltage of 380 V has an output from the secondary winding of 1100 A at 6 V, loading 6·6 kVA, which is connected to the disc of the saw and the holder of a graphite electrode. On touching the electrode against a tooth, current is automatically delivered to a transformer and the tooth is heated. After the elapse of 4 sec, controlled by a time relay, the tooth is heated sufficiently to harden a 3 mm layer at the point of the tooth which has a tip angle of 45–52° and a thickness of 7–10 mm. The hardening effect was very considerable.

The direct hardening of gear wheels H. Sigwart (*Härt. Techn. Mitt.*, **12**, (2), 9–22) The physical properties required in hardened gear wheels are outlined, including the need for good fatigue resistance. Experiments are described in which it is shown that the required properties can be obtained by gas carburizing followed by quenching. The advantages of an Mo–Cr alloy steel for this purpose are pointed out.

Mains-frequency induction heating of heavy steel rolls H. Geisel (*Electrowärme*, 1959, **17**, Mar., 68–71) As heat distribution is uniform round the surface, rotation is not necessary. An actual installation is described and compared with gas heating. Costs are also considered.

A new austenitic steel for nitriding M. F. Alekseenko and A. G. Andreeva (*Stal'*, 1959, (1), 78–81) A steel containing 19%Cr, 8%Ni and 2·5%W is suggested as a replacement for existing nitriding steels.—R. S.

Fundamental study on cyaniding and carbonitriding. II. On the carbonitrided cases F. Yoshikawa (*Nippon Kinzoku*, 1957, **21**, Dec., 699–703) Pure iron was carbonitrided using mixtures of ethane, ammonia and hydrogen, and changes near the beginning of austenitization were studied. The double-stage contraction beginning at 590–605° and 620–650°C is caused by γ-generation. Thick layers of high-N low-C $\epsilon + \gamma'$ and high-N high-C $\theta + \epsilon + \gamma'$ were found. The reduced or uneven surface hardness of annealed specimens is caused by irregular black spots denoting concentration changes during cooling.—K. E. J.

The production of carrier gases for gas decarburization T. Schmidt (*Härt. Techn. Mitt.*, **11**, (2), 9–22) The principles underlying the use of carrier gases in gas carburizing are outlined, some typical examples discussed, and some examples of plant used for the production of carrier gases are described, including plant for the modification of town's gas for the purpose.

Aerodynamics of bell type furnaces for bright annealing V. I. Mitkalinnyi and N. G. Molchanov (*Stal'*, 1959, (2), 176–180) The pressure inside the muffle for bright annealing of coils is determined by the consumption of protective gas, the air-tightness of the valve or seal and the amount of gases circulating within the muffle. The distribution of pressure is determined by the resistance of various parts of the hearth. The atmosphere distribution up the charge is approximately the same for single or double wall muffles.—R. S.

The production of a protective atmosphere for bright annealing F. I. Zenchenko and Ya. A. Peker (*Stal'*, 1959, (2), 151–155) To obtain a first class surface or cold-rolled strip the atmosphere must be dried to a dew-point of ~−30°C with 3–5% H_2, up to 1·5% CO_2 and 3–4%CO. To obtain constant composition stable calorific value of the initial gas an automatic maintenance of gas/air ratio is needed. Reductions in the consumption of monoethanolamine, alumino-silica gel and Freon are most important in reducing the cost of the protective gases.—R. S.

Generation and use of prepared atmospheres in the annealing of low carbon steel strip G. J. Campbell (*Ind. Heat.*, 1958, **25**, Sept., 1749–1764) The defects encountered after annealing tin plate and low-carbon steel coils are described together with their causes. Preventive measures are discussed, including the possible use of a H_2–N_2 atmosphere.—A. G.

Heating and cooling of flat strip: I A. H. Vaughan (*Ind. Heat.*, 1958, **25**, Oct., 1954–1963, 2180) To assist in the design of modern controlled-atmosphere strip furnaces graphical data are given on heating and cooling rates under various conditions. **II** (Nov., 2216–2226) The factors of radiation, convection, heat content and emissivity are discussed to enable ideal heating and cooling curves to be applied in practice.—A. G.

Effect of annealing time on the structure and transformation behaviour of plain carbon steels H. Borchers and G. Saur (*Stahl Eisen*, 1959, **79**, Feb. 19, 210–215) The grain size of ferrite in 0·35%C steels, the ferrite : pearlite ratio and Ar_3 and Ar, points are only affected by annealings for rather short times (up to 2 h), whereas for long-time annealings their relations are lost. No explanation for this behaviour is offered at present.—T. G.

Protective atmosphere improves annealing of malleable iron castings (*Ind. Heat.*, 1958, **25**, Oct., 2010–2012) The adoption of an atmosphere free from CO_2 and of low dew-point is said to have cut annealing time, and reduced decarburization and rejects.—A. G.

Modern high-speed continuous annealing line for tin plate scheduled at J. and L.'s Aliquippa Works (*Ind. Heat.*, 1958, **25**, Sept., 1782–1784) The new high speed continuous annealing line described is said to be the first with co-ordinated mechanical and electrical drives throughout.—A. G.

Peculiarities of the distribution of magnesium during the annealing of magnesium forging irons M. A. Krishtal, I. P. Fominykh, and E. P. Rikman (*Lit. Proizv.*, 1958, (8), 10–11) In order to discover at what points the formation of graphite produces Mg enrichment of the graphite, and study the effects of annealing at this temperature, and of the composition of the cast iron, and especially of the Si content, on the redistribution of Mg between the matrix and the graphite, an investigation was carried out on specimens of two irons, one modified, the other grey. In the initial state the distribution of Mg was almost identical in both irons. Annealing at 950° and 1050° did not in general produce any noticeable redistribution of Mg, even after 50 h heat treatment, although in the spheroidal graphite forming directly in the melt (in thick sections of the specimen) an increased Mg content was observed. In these graphitic pockets the content rose from 0·041–0·072% while the general level remained at 0·029–0·035%. There was thus a discrepancy in the behaviour of Mg in one and the same iron. On the other hand in the grey iron, redistribution occurred freely in general. While the diffusion coefficient of Mg in the modified forging iron was only 24, in the grey iron it attained 148. It is concluded that this and other differences in behaviour are caused by the difference in Si content. Si is dissolved in the matrix and associates with Mg. The higher Si content of the grey iron leads to greater Mg solubility in the matrix, and association of the Si and Mg atoms inhibits Mg migration from the austenitic matrix to the graphite during annealing. In low Si content irons Mg atoms are loosely bound and readily migrate to the graphite. It is therefore considered that Si reduces the diffusion coefficient of Mg from the matrix to the graphite.—M. T.

Water and air annealing of high speed steels (SKH 8 and SKH 6). (Study on high speed tools–XVIII) H. Hotta (*Tetsu to Hagane*, 1958, **44**, Nov., 1284–1287) A comparison of steels with 0·65%C and 15·92%W and 0·78%C and 10·9%W respectively (analyses given) either water quenched or air cooled after annealing at 700–900° and cooling from just below the transformation point (800°C) is made by measurements of hardness and metallographic examination, the process being repeated up to ten times. Machinability was examined.

Heat transmission in a coil annealing furnace K. Tanaka (*Tetsu to Hagane*, 1958, **44**, Oct., 1165–1170) The difference between maximum and minimum temperature in steel coils after annealing for 25 h was 30–60°C although calculations showed that the temperature difference should be reducible to 5°C or the time to reach a temperature difference of 30°C should be reduced to 15 h The causes of the discrepancy between practice and theory are discussed and recommendations are made for the design of a furnace that fulfils the requirements.—T. G.

Annealing welded blanks made of high speed steels B. L. Aleksandrovich and M. I. Gol'dvasser (*Metallov. Obra. Met.*, 1958, (8), 59–60) Isothermal annealing of welded blanks at the 'FREZER' plant is described in detail.—L. H.

Texture formation during the annealing of cold-rolled transformer steel L. V. Mironov (*Izvest. Akad. Nauk. Seriya Fiz.*, 1958, **22**, (10), 1231–1236) During the annealing of these steels after two-stage rolling with an intermediate anneal or after a single rolling with a reduction exceeding 75%, secondary recrystallization occurs which determines the preferential orientation of grains. The important temperature for a complete texture is that at the beginning of the secondary crystallization, when the most precise orientation of the nuclei of growth occurs. Since at this temperature the number of 'centres of growth' is small and the linear rate of their increase slow, the time needed for a complete change may reach 6 h.

Softening treatment of high-alloy cemented steels Yu. G. Vyshkovskii (*Metallov. Obra.*

Met., 1958, (8), 43–46) High temperature tempering does not reduce the surface hardness of 18KhNVA steel (approx. 0·15%C, 1·5%Cr, 4%Ni, 1%W) to permit its machining after carburization. A treatment is suggested which involves the use of weak carburizing mixtures and decomposition of residual austenite at low temperatures prior to tempering at up to 620–630°C.—L. H.

Effect of heating rate in heat-treatment. II. Effect of heating rate on properties of heat-treated 13% Cr stainless steel S. Sakui, T. Mori, and C. Yamamoto (*Tetsu to Hagane*, 1959, **45,** Feb., 117–122) Heating rates of 3000°C/sec and 10°C/min were used. With rapid heating, the recrystallization temp. was 100°C, the grain size immediately after recrystallization was smaller, and there was more random directionality. The A, transformation occurred at 900°C with slow and at 950°C with fast heating. Martensite formed by quenching was finer in the rapidly-heated specimen.—K.E.J.

Improving the quality of hollow drill steel and increasing the lives of drills V. F. Isupov (*Stal'*, 1959, (5), 461) A note on research by the Serov Combine. Fatigue fractures occurred, 60% in the shank and head. A furnace with careful control for heat treatment doubled drill life. Other improvements were also made.

Mathematical treatment of the time-temperature variation for the heating and cooling of finite solid cylinders, as a basis for the heat treatment of large forgings H. Uhlitzsch (*Neue Hütte*, 1959, **5,** May, 277–287) Equations for time-temperature variations within a finite solid cylinder are derived. The influence of the end circular surfaces of a solid cylinder and of the surface of a disc on the calculations are examined, and two practical examples are worked out in detail (13 refs.).

The heat treatment of structural members by oil or hot bath hardening compared with intermediate stage transformation B. Finnern (*Draht*, 1959, **10,** April, 147–151) The normal heat treating methods and intermediate stage transformation are compared, and it is concluded that the improved strength properties obtainable by the latter treatment are only possible with strict control of austenization and quenching conditions, together with careful selection of the steel

Toughening high-strength steel by warm working E. J. Ripling (*ASTM Proc.*, 1958, **58,** 943–954) The poor toughness of SAE 1340 steel may be improved (× 2 to × 7) by warm working with increase of yield strength, and a small increase in tensile strength and ductility. Warm worked SAE 4340 shows a somewhat smaller improvement in toughness with a smaller loss of hardness.

Case hardening D. Flament (*Mét Constr. Méc.*, 1959, **91,** April, 261–262) A brief outline of the physico-chemical characteristics of the case-hardening process and its variants.

Study on a continuous gas carburizing furnace. II. A. Tsutsui and T. Furumoto *Nippon Kinzoku*, 1958, **22,** May, 221–225) Tests on SCM 21 steel show that there is little difference in residual stress produced between the gas and pack carburizing methods. The max. value of compressive stress in the carburized portion decreased with increase in case depth (11 refs.).—K.E.J.

Carburizing and decarburizing in the mains frequency induction furnace M. E. Calamari (*J. Four. Elect.*, 1958, **63,** Nov.–Dec., 225–228) An account is given of the carburization of liquid pig iron in the mains frequency induction furnace, and of the refining of pig iron to steel.

Improvements in induction heating W. E. Benninghoff (*Met. Prog.*, 1959, **75,** Feb., 66–70) A general review including heating at low temperatures for, e.g. stress-relieving.—T.G.

Decarburisation of steel in heat treatment B. E. Lyubinskii and M. I. Vinograd (*Stal'*, 1955, (6), 540–544) Surface decarburization below the critical temperature (Ac_1) is observed only with Si and Si–Mo steels. It is most intensive above the critical temperature. The depth of decarburization also increases with increasing temperature.

Utilisation of a controlled atmosphere in annealing blackheart malleable cast iron (*Fonderie*, 1958, July, 338–339) The use of a controlled atmosphere in the annealing treatment is discussed, and the conclusion drawn is that there is no advantage to be gained in the case of a new and well luted electric annealing furnace.

Heating and cooling of flat strip. III. A. H. Vaughan (*Ind. Heat.*, 1959, **26,** Jan., 32–34, 36, 38–40, 42, 44) Heating and cooling curves are given for strip in various atmospheres and the use of the curves for calculation of thermal processes is described.

Increased rates for annealing sections V. F. Isupov (*Stal'*, 1959, (5), 461) A note on research at the Serov Combine. Better timing, increased charge, and the use of two-way bottom firing raised output from 850 to 1400 t/month.

Dimensional change due to annealing after cold-working of metals M. Okada and T. Watanabe (*Nippon Kinzoku*, 1958, **22,** Aug., 440–442) With low-carbon steels, the change is in the direction of working, with austenitic stainless steels in the opposite direction. Dislocations piled up during working tend to migrate in a direction which relieves their high stress, and this depends on the direction of working and the structure of the metal.—K.E.J.

Producing mild electrical iron with low coercive force and minimum age-hardening characteristics N. P. Khetvin (*Stal'*, 1959, (5), 460) A note on research at the Hammer & Sickle works. Effects of ageing are noted. Non-ageing conditions could not be found but annealing in H_2 reduced magnetic ageing effects.

Heat treatment of Bessemer rails A. D. Kutsenko (*Stal'*, 1959, (6), 567) A note from Dzerzhinsk A normalizing furnace and a hardening machine are used. Properties as rolled, and after normalizing and hardening are tabulated.

Hot-bath quenching of a low W–Cr tool steel (8K82) in the low temperature range. II. Length changes and toughness on quenching, ageing, and tempering I. Tatsukawa (*Tetsu to Hagane*, 1958, **44,** Dec., 1372–1377) Cylindrical specimens of 1·0C, 1·0Cr, 1·4W tool steel were investigated. Specimens obtained by hot-bath quenching below the Ms point, ageing at room temp., and tempering at 180°C showed greater length stability and toughness, compared with those oil-quenched and tempered normally.

Improving the mechanical properties of reinforcing steel by means of heat treatment E. S. Tovpenets, N. I. Goncharenko, A. S. Babin, and G. Z. Shcherbina (*Stal'*, 1959, (4), 364–367) Reinforcing section low-C St 5 steel can be improved by quenching and tempering, increasing impact strength, specially at low temp. as well as tensile strength and yield point. The effect of welding is not uniform and depends on the method used. The economics of quenching from rolling heat are somewhat inferior to those of quenching from a special reheating temperature.

A new technology for the conversion of 1Kh18N9T steel (with the object of minimizing α-phase) I. P. Zabaluev (*Stal'*, 1959, (6), 567) A note from Dneprospetsstal. Tempering at 1100° for 2–2½ h followed by quenching is used.

The influence of slow cooling on the properties of Bessemer rails A. M. Karpunin (*Stal'*, 1959, (3), 269) Rails of type R-43 from three melts with 0·73%, 0·65%, and 0·56%C respectively were tested after different processes of cooling. Slow cooling reduced the u.t.s. and impact strength and increased brittleness.

Improving the heat treatment of section material by raising the quality of tempering and increasing furnace output I. P. Zabaluev (*Stal'*, 1959, (6), 567) A note from Dneprospetsstal. Methods of hastening the tempering process are mentioned.

FORGING, STAMPING, DRAWING, AND PRESSING

The forging process in hammer and press, with special reference to the rise J. Stoter (*Werkstatistechn.*, 1959, **49,** April, 223–230) The results are described of an investigation of the deformation processes in press forging, with particularar reference to the upsetting process.

New method of determining forgeability of metals D. I. Berezhkovskii (*Zavods. Lab.*, 1958, **24,** (7), 858–860) Equipment for simulating press-forging conditions is described. The minimum reduction at which the first crack appears is observed and here this is correlated with metal composition, inoculation conditions, gas atmosphere, and temp. Formulae for calculating minimum critical reduction and forgeability are given. Practical uses of the data are indicated.

Electric-hydraulic forging presses with crank drives A. Hertl (**Stahl Eisen*, 1959, **79,** Apr. 16, 477–485) Principles, examples, advantages and useful applications of electric-hydraulic forging presses are described. This type of press combines the advantages of the hammer with those of the hydraulic press for hammer forging, the power required for the crank drive that supplies the hydraulic pressure is usually lower than for pure hydraulic presses.—T.G.

Forging presses with below-floor-level drive E. Howahr and H. J. Pahnke (**Stahl Eisen*, 1959, **79,** Apr. 16, 485–494) Principles of design and advantages and disadvantages of forging presses having below-floor-level drives are discussed. The principal disadvantage of fundamental importance is that with below-floor-level drive the moving masses are very much greater than with the conventional type of drive. This requires very much heavier presses to get the same pressure. The advantages on the other hand are obvious so that the below-floor-level-drive forging press may well have a future.

Control of hydraulic presses W. Dohrn and H. Robra (**Stahl Eisen*, 1959, **79,** Apr. 16, 509–514) After reviewing the various types of hydraulic forging presses, the authors describe and discuss conventional control equipment, advantages and disadvantages of various types of control elements and their useful application High-speed forging presses (up to 140 strokes/min) require special control equipment that is described.—T.G.

Simple feeder automates high-speed press (*Metalw. Prod.*, 1959, **103,** Feb. 6, 242–243) The Carter feed attachment is described. It locks and releases strip and feeds thin, soft materials at >400 strokes/min.

Spin forging (*Machine shop Mag.*, 1959, **20,** June, 354–356) The process of shaping steel by this method using the Hufford Corpn. machines is described and illustrated.

Giant 'spin-forge' advances space age metal forming art; boosts material strength, cuts production cycle 50% N. Wood (*Western Metalw.*, 1959, **17,** Feb., 37–38) A combined metal spinning and roll forging machine capable of forming stainless steel 1 in. thick is being installed.

Dyzacking J. A. Grainger (*Sheet Met. Ind.*, 1959, **36,** Apr., 271–277, 279) A drop stamping process for small numbers of parts to close tolerances is described. A die is needed but a lead slab takes the place of the conventional punch. In comparison with deep-drawing tool cost is low but the time taken is rather long. It is particularly useful for prototype production.

Factors affecting the transition temperature of forgings used in power-generating equipment B. Cina and P. Jubb (*JISI*, 1959, **193,** Dec., 329–349) [This issue].

New units boost capacity for forming heavy plate (*Iron Age*, 1959, **183,** Mar. 12, 126–127) A description is given of the installation of special equipment for the manufacture of pressure or process vessels and nuclear reactors. Items include a 2500-t flanging press, large capacity plate bending rolls and a furnace for the large steel plates.—A.G.

Controlled explosive blasts hardness into steel W. A. Harper (*Product Eng.*, 1959, **30,** Apr. 13, 62–63) Velocity-impact hardening (VIH) and its application to Mn steel costing surfaces is described. The use of sheets of PETN with additives is outlined.

How to design and check bends in welded steel tubing (*Iron Age*, 1959, **183,** Feb. 26, 85–88) Minimum bend radii are given for different gauges of tube. Practical considerations in planning a bending operation are discussed.

From wire to bolt design; working life and efficiency of the forming tools K. Sieber (*Wire*, 1959, Feb., 14–21) Effect of tool shape on the drawing process, effect of methods and intensities of working on stresses imposed on dies and forming tools, application of principles of single-stage to multi-stage working, design of extrusion die casings, and factors relating to the best conditions for the hot heading of bolts are amongst the topics discussed.

Insulation advances open-type motor applications (*Blast Furn. Steel Plant*, 1958, **46**, Oct., 1075, 1097) Silicone-rubber insulation and epoxy resins are the basis for the open-type electric motors, as they give a glass-like surface that shuns dust and dirt and that is moisture-repellent. They are suitable for metal processing.—T.G.

Experimental investigation into the cold reduction of tubes V. I. Sokolovskii, V. S. Gashukov, and M. V. Lirman (**Stal'*, 1958, (12), 1112–1117) ShKh15 steel and non-ferrous alloys were tested in a KhPT–E150 cold reducing mill with a new lightweight roll housing. Feed and angle of rotation of the workpiece, rolling load, forces acting on connecting rods, tow bars, feed screw, mandrel bar and camshaft, stresses operating at points of the housing and rail track and stresses operating in the ends of the sledges were calculated. Wire gauges were used with 8-loop oscillographs. The measurements are given and discussed.

Stronger carbon steel bars E. S. Nachtman (*Mat. Design Eng.*, 1959, **49**, Mar., 98–99) Elevated temperature drawing (in the 200°–1200°F range), its effects on C1018, C1080, C1144 and 4140 steels and parts made by it are discussed.

Pipe coating adds to draw die life (*Steel*, 1959, **144**, Feb. 23, 82–83) A new oxalate coating is described which protects the surface of stainless tubing and provides a foundation for die lubricants. Large increases in drawing speed are claimed with longer die life.—A.G.

Shape, fasten, engrave, test materials with explosives H. P. Tardif (*Mat. Design Eng.*, 1959, **49**, Feb., 82–87) An outline of each of these processes is given with illustrations and a general account of the processes and parameters involved.

Why explosive forming works J. S. Rinehart, V. Philipchuk, and J. Pearson (*Steel*, 1959, **144**, Jan. 19, 62–65) Explosive forming increases the elongation of carbon steel to 70%, can harden aluminium 95% without changing size and is able to shape refractory metals. The mechanism of the process is discussed.—A.G.

Pressure required for transformation twinning in explosively loaded low-carbon steel D. R. Curran, S. Katz, J. J. Kelly, and M. E. Nicholson (*Trans. Met. Soc. AIME*, 1959, **215**, Feb., 151–153) The results of an investigation into the explosive loading of a series of steel wedges were evaluated by a metallographical examination of the wedge sections.

Explosive forming blasts complex shapes in fraction of time by conventional methods Ryan Aeronautical Co. (*Western Metalw.*, 1959, **17**, Apr., 52–53) A method operating under water is used with a variety of explosives.

Do it yourself: Explosive cutting (*Steel*, 1959, **144**, Mar. 23, 104–105) In the method described a special explosive is cut to the required shape, glued to the metal and detonated by an electric blasting primer.—A.G.

Carbon steel flat wire (*AISI Steel Prod. Man.*, 1959, Jan., pp.41) This replaces both the former low carbon steel flat wire and the carbon spring steel flat wire manuals.

The Bauschinger effect in the wire industry J. J. Parr (*BHP Techn. Bull.*, 1959, **3**, Mar., 15–19) A review of the effect and its use in the wire industry for softening cold-worked metal is given.

Extrusion of steel (*Machinery Lloyd*, 1959, **31**, Jan. 10, 46–49) An account of the operation of the Sejournet process at Low Moor.

Who uses extrusions (*Prec. Met. Mold.*, 1959, **17**, Feb., 33–36) Examples of parts, mostly non-ferrous, are illustrated.

Bearing cups cold formed (*Steel*, 1959, **144**, Feb. 23, 93) The application of cold extrusion in the manufacture of universal joint bearing cups is described. Subsequent machining is minimized and savings in material are reported.—A.G.

Stainless steel extrusions R. E. Paret (*Mach. Design*, 1959, **31**, Jan. 8, 114–117; Jan. 22, 118–121) Advantages and limits of the process, the properties of extrusions, and the production of solid and hollow intricate shapes are discussed. Design is then considered and applications are reviewed with consideration of tolerances, and examples.

Ordnance extrusion know-how aids industry (*Metalw. Prod.*, 1959, **103**, May 22, 891–896) Press work at the Royal Ordnance Factory, Birtley, is surveyed, especially in the production of gear components.

Cavity formation and enfolding defects in plane strain extrusions using a shaped punch W. Johnson (*Appl. Sci. Res.*, 1959, **8A**, (2–3), 228–236) Expressions are obtained for the best upper bound load for square dies using a punch with an inclined face and the choice of this angle to delay cavity formation is considered. A mechanism whereby oxide layers on the rear of the billet may become entrained down the centre of the extrusion is envisaged.

Cold extrusion of steel B. Kaul (*Usine Nouv.*, 1959, **15**, April 9, 37, from *Machine Moderne*, 1958, March) The production of cylinders from steel bars with 0·12%C, Rockwell B hardness 50–60 and 127 mm × 85·7 mm dia. is described.

Cold extrusion shows one way to diversify with profit R. H. Eshelman (*Iron Age*, 1959, **183**, Feb. 12, 95–97) The field for cold extrusion of parts is explained, and an example cited of the production of a small gear-like part in an automatic press system.—D.L.C.P.

ROLLING MILL PRACTICE

The development of the theory of rolling F. Wiesner (*Hutn. Listy*, 1958, **13**, (11), 987–990) The various theories of rolling from the simplest up to the hydrodynamic theory proposed by Knescke (*Bergakademie*, 1954, 1–11), are discussed.—P.F.

Production planning in the rolling mill A. Struss (*Stahl Eisen*, 1959, **79**, Feb. 5, 141–145) Managerial.—T.G.

Crack depth determination in rolling mill roll passes N. P. Khetbin (*Stal'*, 1959, (6), 550) A research note from the Hammer & Sickle works. Tests on an ultrasonic defectoscope using artificial 'defects' are described. Depths of cracks in mill rolls were also correctly indicated. **A process for straightening stainless, work-hardened and mild steel in a tension leveller** (550) It is shown that where there is a sufficient difference between yield-point and u.t.s. in the semi-work hardened state the sheet can be extended without danger of fracture. The straightening process is discussed.

Some remarks on the theory of the rolling process in the planet-type mill L. Hellebrand (*Hutník*, 1958, **8**, (11), 373–376) Some aspects of the nature of the deformation occurring on rolling in planetary-type mills are discussed.

Hot-workability of silicon steels J. Telecký (*Hutník*, 1959, **9**, (4), 121–128) It was found that dynamo steels with Si contents exceeding 1·8% always have a two-phase structure, assuming the usual carbon contents. Such steels are difficult to roll because of the structural heterogeneity. Steels containing 10–20% of ferrite at the rolling temperature are particularly prone to tear-formation. A phase diagram has been constructed which shows that if the carbon content is kept below 0·06%, and below 0·1% in some special cases, the difficulties are minimized.—P.F.

The measurement of the degree of deformation in skin-pass rolling: foundations — operation — experience J. Billigmann, J. Lenze, and D. Schönert (**Stahl Eisen*, 1959, **79**, July 9, 977–989) After discussing the relation between the reduction obtained by skin-rolling and the properties of deep-drawing steel and strip used for packaging, the authors review methods for the measurement of the properties after the skin-pass. They discuss the bases of the measurement of the deformation in skin-rolling, which is entirely different from that employed in normal rolling practice. Design and operation of modern equipment for measuring the extension of the strip in skin-rolling, accuracy obtained, and effect of rolling speed are described in detail (46 refs.).—T.G.

A mechanism for the delivery of metal into the rolls of a rolling mill B. D. Smolovikov and L. Shevchenko (*Stal'*, 1959, (5), 441–443) A pusher-type charger is described. Great savings of labour are expected when the device is fitted at the front and back of the (3-high universal) mill.

Maximum angles of engagement in rolling A. P. Chekmarev, A. A. Dinnick, A. P. Grudev, M. S. Mut'ev, N. P. Spiridonov, and Yu. V. Vorotyntsev (*Stal'*, 1959, (5), 444–445) A discussion of the coefficient of friction in the process of engagement with a consideration of the effects of scale. B. P. Bakhtinov (445–446) The forces diagram is shown and expressions are given of various assumptions for maximum angle, forward flow, and spread. A. I. Tselikov (447). Remarks on the work of Bakhtinov in general confirmation of his conclusions.

The effect of the rate of deformation during rolling on the distribution of the specific roll pressure M. L. Zaroschinskii and A. I. Grishkov (*Stal'*, 1959, (5), 433–436) Factors influencing the distribution of specific pressure along the arc of contact in hot rolling are set out. Conditions are defined in which the rate of deformation is the most important factor. The conditions are formulated.

Practical investigation on work rolls for cold rolling Y. Kuwabara, Y. Miwa, and K. Ariga (**Tetsu to Hagane*, 1957, **43**, Jan., 24–28) The results of several years' experience in cold rolling on a 4-high reversing cold strip mill are summarized. Relations between roll hardness, life, and cracking are established, and the results of structure examination under the electron microscope are discussed, the structures being related to roll life.

Cast steel rolls for thin sheet rolling A. Šprenel (*Slévárenství*, 1959, **7**, (4), 133–138) [In Czech] The most important technological precautions necessary in the production of high quality cast iron rolls are discussed. Performance and production technology of homogeneous and compound rolls are compared. A new method of heat treatment of homogeneous rolls by isothermal annealing at temperatures up to 1120°C was studied and was found to be promising.—P.F.

New methods in the production of rolls in the Třinec steelworks V. Viochna (*Slévárenství*, 1959, **7**, (4), 131–133) An account is given of recent production technology relating to cast rolls of spheroidal iron, e.g. compound rolls for sheet rolling mills, homogeneous rolls, and rolls with precast grooves.—P.F.

Raising the quality of cast iron rolls for section rolling V. I. Malyi and L. F. Molotkov (*Stal'*, 1955, (6), 558–560) The suggestion that rolls with cast grooves have a longer service life (less wear and fractures) is contested, and is opposed by experience gained at the Dzerzhinskii Plant.

The roll pass design for, and rolling of, lightened channel-section No.40 I. I. Kuchko and N. P. Kudryavtsev (*Stal'*, 1959, (6), 538–543) Full directions for rolling a section lightened by 10·61 kg/m or 18% are given.

Maintaining sheet mill camber by continuous measurement of neck temperature N. F. Dubrov (*Stal'*, 1959, (6), 551) A note from the Ural Research Institute. Chromel-copper thermocouples are inserted into apertures in the bearings and temperature drop between roll necks is controlled to ±20°C. Sheet rejects are reduced one-third to one-half. **Perfection of techniques for cold-rolling transformer steel** (551) Decarburization to 0·02% by black annealing, increased reduction at the second cold rolling and intermediate holding at 950° and vacuum annealing at 1140°C are used.

Knurling of rolls H. Neumann (**Neue Hütte*, 1959, **4**, April, 244–246) A summary of the report on roll knurling presented by Mauer and others at the meetings held at the Hagen-Haspe and Rheinhausen works in March and November 1958 respectively.

Roll cracking in sheet mills E. Gerlach (**Metallurgie u. Giessereitechnik*, 1952, Jan., 14–17) The properties of a good chill roll are described, phenomena relating to heat transfer and stress development during rolling discussed, and the effects of Mo additions and roll design in improving hot strength are reviewed. Recommendations are made for operating the mill so as to obtain the best life from the rolls.

Fire cracking of cast iron rolling mill rolls J. Thieme (**Metallurgie u. Giessereitechnik*, 1952, Jan., 17–18) It is shown that thermal stresses were responsible for the appearance of fire cracks, widening of the cracks being due to mechanical loading, although modified by the structure, and aggravated by improper working conditions.

A new technological plan for rolling ingots in an 1150 blooming mill A. D. Kutsenko (*Stal'*, 1959, (6), 551) A note on the double ingot process where the second piece is engaged before the first has left the centre of the rolls.

Simultaneous rolling of two ingots in a 1150 blooming mill A. P. Chekmarev, V. I. Melcshko, V. L. Pavlov, V. D. Chekhranov, G. E. Tsukanov, I. K. Shafran, and M. P. Ivanin (*Stal'*, 1959, (3), 243–247) A process of timing and adjusting the passes to handle two ingots simultaneously and increasing output 15–30% according to the size of the blooms and ingots is described.

Experimental rolling of 350 mm dia. billets V. K. Yatsura (*Stal'*, 1956, (6), 552) A note from the Zakavakzsk Metal Works. Rolling of 6-t ingots of 20 steel was unsatisfactory in the existing mill.

Flow of metal and structural phenomena during hot rolling with high draughts Z. Wusatowski and B. Hoderny (*Arch. Hutn.*, 1959, **4,** (1), 63–80) Tests on metal flow in the hot rolling of low-C steels with draughts of 60–90% were made. Holes were drilled in specimens and filled with wire of practically the same composition. X-ray studies confirmed that cracks were absent. Steel bars 40 × 40 mm with 0·15% and 0·35%C showed grain size reductions in the centre while layers in contact with the rolls show strain-hardening due to the cooling effect. Tensile tests were made on specimens from various locations and the results are evaluated.

Stress and deformation studies for sandwich rolling hard metals R. R. Arnold and P. W. Whitton (*Inst. Mech. Eng. preprint*, 1959, 13) In the absence of a Sendzimir or planetary mill and for relatively small outputs the sandwich method can be used. Theory and practice are examined and it is shown that reductions in load up to 60% can be achieved. A method of adapting cold-rolling theory to the calculation of loads is given based on a criterion of simultaneous yielding in hard and soft layers. Optimum conditions are discussed.

The effect of carbon, manganese, chromium, nickel and molybdenum on the spreading of steels during hot rolling W. Grosse and H. Gottwald (*Stahl Eisen*, 1959, **79,** June 11, 855–866) The displacement of material taking place during the hot-rolling of steels at various temperatures was studied for various degrees of working and for various compositions. For the same rolling conditions spreading depends on the temperature of working and on the composition of the steel. The individual alloy additions act in different ways on spreading. The studies are used to derive a factor for any given composition for inserting in Sedlaczek's spreading formula.—T.G.

The measurement of roll forces and the establishment of pass sequences of an automatic seven-stand hot-strip finishing mill H. Lampmann and W. Volkening (**Stahl Eisen*, 1959, **79,** May 28, 777–785) The seven-stand tandem mill consists of identical four-high stands, *i.e.* the results obtained in the roll-force measurements on the individual stands give a true picture of all the factors involved. The results are compared with calculations from formulæ published in the literature. Based on the measurements, an optimum pass sequence was devised. In the discussion, it is disputed that the pass sequence derived is an optimum one.—T.G.

Camber variation during rolling A. R. E. Singer (*Sheet Met. Ind.*, 1959, **36,** Feb., 134–139) The use of these devices for the correction of shape defects is described. Various factors in mill operation controlling effective camber and giving rise to transverse variations are mentioned, with special reference to four-high mills. During working the effective camber varies with initial shape and load variation and distribution and effects of temp. and wear are superimposed. The initial camber ground on the wheel therefore only applies to a limit range of widths and reductions. Existing schemes for camber variations are outlined and development of a variable-camber mill is described in which the use of jacks and wedges is envisaged. Possible advantages of the design are set out.

Roll grinding (*Iron Steel*, 1959, **32,** Feb., 71–74) A description of the design of the new Churchill heavy-duty travelling wheelhead machine and its application to roll grinding is given.

Dressing of rolling-mill rolls (*Iron Coal Trades Rev.*, 1959, **178,** Feb. 6, 321–325) A description is given of the new Churchill heavy-duty roll grinding machines one of which has recently been installed at the SCOW Abbey works. Special features include an automatic electronic feed which makes possible a high rate of metal removal.—A.G.

On the back-up roll for a 16½ in. diameter, 49 × 42 in. four-high reversing mill Y. Miwa, H. Matsunaga and E. Kameyama (*Toyo Kohan* 1954, **3,** May, 45–48) Forged steel sleeved rolls having hardnesses in the range 60–63 HS are most suitable for back-up rolls in the reversing cold mill, having much longer lives than solid or sleeved cast rolls.—K.E.J.

Air gap limits chill in cast iron rolls J. D. Keller and N. R. Arant (*Foundry*, 1959, **87,** Feb., 81) A brief report on a study of the formation of an air gap between mould and solidifying metal in the production of cast iron rolls. The air gap that prevents extraction of heat at high rates exists from the beginning, but it is very small then but enlarges rapidly, and after a few minutes more slowly. The roll diameter has not a great influence on the width of the gap.—T.G.

[Concerning] the chill depth of the chilled roll for a pull-over type tin plate mill Y. Miwa, S. Ueda and E. Kameyama (*Toyo Kohan*, 1953, June, 59–64) Roll breakage is attributed mainly to heat stress caused by variable temp. distribution in the roll. The optimum chill depth is 5–8 mm, with an eccentricity of clear chill of 2 mm.—K.E.J.

Mechanical inching drives H. K. Fish, J. R. Shields, E. W. Barth and K. W. FitzSimmons (*Iron Steel Eng.*, 1959, **36,** Jan., 109–111) An account is given of the construction and operation of inching drives fitted for the aligning roll and drive spindle when changing the rolls in a roughing mill.

Transverse gauge variation in strip and sheet rolling K. Saxl (*Proc. Inst. Mech. Eng.*, 1958, **172,** (22) 727–742) Roll deformations in four-high and two-high mills are formulated and roll cambers and corrections for edge thinning are obtained. Methods of compensation are discussed and defects caused by variations of thickness are mentioned.

Bearing manufacture requires precision (*Can. Metalw.*, 1959, **22,** Mar., 12–14) A description is given of the manufacture of large roll neck bearings at the Canton (Ohio) plant of Timken Co. The five principal production steps of forging, green machining, finish grinding, assembling, and packaging are discussed.—G.F.

Blooming mill replacements (*Engineer*, 1959, **207,** Feb. 6, 223) An illustrated account of the 48 in. mill at Corby and the 42 in. mill at Irlam.

New blooming mill at Irlam (*Iron Steel*, 1959, **32,** Mar., 118, 120) Some technical data are given of the 42 in. mill installed at the Irlam Works of the Lancashire Steel Corporation, and built by Lamberton & Co. Ltd.

Installation of 48-inch blooming mill at Corby (*Brit. Steel*, 1959, **25,** Feb., 60–62) An account is given of the changeover last Dec. from the 40-in. blooming mill at Corby to the new 48-in. mill, which was completed after a shutdown of 10 days.

Stewart and Lloyds' new blooming mill (*Iron Coal Trades Rev.*, 1959, **178,** Feb. 6, 307–310) By pre-planning and the use of a labour force of 400 men a 40-in. blooming mill at the Corby works was replaced by a 48-in. mill in record time. The first ingot was put through the new mill 10 days and 10 h after the shut-down.—A.G.

The Steel Company of Wales replaces slabbing mill in 12½ days (*Blast Furn. Steel Plant*, 1959, **47,** Feb., 190–191) The changeover from the old to the new mill in the Abbey Works of the Steel Company of Wales last November is described.—T.G.

Welsh mill rebuilt in less than a fortnight (*Steel*, 1959, **144,** Jan. 12, 78–79) A brief account is given of the replacement of an old slabbing mill by a new 2660-t mill in 12½ days.—A.G.

Slabbing mill changeover at Abbey Works (*Brit. Steel.*, 1959, **25,** Jan., 26–28) The changeover at the Abbey Works of the Steel Company of Wales from the old slabbing mill to the universal slabbing mill, completed in 12½ days, is described, with illustrations showing various stages of the operation.

Operation changeover (*Steel Rev.*, 1959, Apr., 38–48) An account of the replacement of the old high lift slabbing mill by a new universal mill at the Steel Co. of Wales in 12½ days.

Increasing the life of cogging mill rolls by work-hardening L. V. Andreyuk (*Stal'*, 1959, (2), 141–145) A description of the device used for work-hardening is given and increased endurance averaging 27·5% was obtained by the improvement in surface condition and elimination of the initial period of reduced strength after turning.

Alloy-steel ingot and bar production in Birmingham (*Foundry Trade J.*, 1959, **106,** Jan. 8, 39–40) An account of extensions of the Spartan Steel and Alloy plant at Aston.

The nature of fissures in 1 Kh18N9T steel L. D. Kossovskii, V. A. Korosh and M. A. Mukhina (*Stal'*, 1959, (2), 147–148) Transverse fissures forming on the faces of blooms are attributed to water dripping on to the surface in the rolls and greatly reducing local ductility, the thermal conductivity being low and the change of ductility with temp. being rapid. Rolling in a mill without water cooling and turning the ingot more frequently reduces the number of fissures produced.

Mechanical manipulation in bar mills E. C. Peterson (*Iron Steel Eng.*, 1959, **36,** Jan., 67–78) Some of the mechanical devices available for handling stock through the guides and panes of bar mills are described and illustrated.

Rationalized roll-pass design in continuous billet mills M. I. Boyarshinov and I. P. Shulaev (*Stal'*, 1959, (2), 137–141) Work at Magnitogorsk is reviewed and changes in pass designs are followed as well as the development in ancillary equipment.

Shipping departments in small-section rolling mills H. Weidemann (*Stahl Eisen*, 1959, **79,** Apr. 16, 543–545) The layout of the shipping shops in rod and section mills are described and discussed.—T.G.

The effect of finishing temperature of hot rolling on the mechanical properties of hot rolled sheet steel N. Hagiwara, Z. Higo and S. Tanaka (*Toyo Kohan*, 1953, June, 31–45) The lower the finishing temp. of hot rolling, the higher are the Erichsen value and mechanical properties and the smaller the grain size after any annealing temp. The rim has similar superior properties to the core, because of cementite and non-metallic inclusions concentrated at the rim-core boundary.—K.E.J.

Making and treating alloy steel plates. I R. R. Fayles (*Ind. Heat.*, 1959, **26,** Mar., 515–522) The author emphasises the extreme care and rigid adherence to operating techniques that are necessary in the production of heat-treated alloy steel plates. Particular difficulties in melting, casting pit procedure, slab rolling and conditioning, and piling and handling treatments, are discussed.—G.F.

Rolling of metals J. I. Greenberger (*Iron Steel Eng.*, 1959, **36,** Mar., 99–107) Development of modern rolling mill practice is reviewed, with examples

Recent developments in design and control of hot strip mills R. W. Barnitz and H. H. Shakely (*Iron Steel Eng.*, 1959, **36,** Apr., 89–101) Productivity was increased at the Aliquippa and Cleveland works of Jones & Laughlin by applying automatic programming control to single-stand reversing primary mills. Details of the plant and controls are given.

Lancashire Steel's new primary mill (*Brit. Steel*, 1959, **25,** Feb., 64–65) A brief description is given of the main features and the installation of the new 42-in. primary mill built and designed by Lamberton and Co. Ltd. for the Irlam works of Lancashire Steel Corporation.

Continuous hot rolling of medium width strip (*Mech. World*, 1959, **139,** Feb., 80–83) An illustrated account of the new Brinsworth mill.

Mannesmann's new seamless mill at Sault Ste. Marie R. Hartenstein and A. L. Thurman (*Iron Steel Eng.*, 1959, **36,** Feb., 139–148) An

outstanding feature of this mill is its complete automation; details of the plant and its operation are given.

Some experiments on temper-passing for cold reduced tinplate Y. Kuwahara, H. Matsunaga, K. Suzuki, I. Kuno and T. Hamada (*Toyo Kohan*, 1953, June, 19–30) Sheets annealed at 700°C are reduced more than those annealed at 630°C for the same temper-pass conditions, and are more ductile. Mechanical properties are little affected by various temper-pass methods for the same reduction. Using the Uni-temper method, surface crystallisation begins at higher temp. and recrystallisation is complete at lower temp. than with the ordinary method.—K.E.J.

Improved lubrication in cold strip rolling J. C. Whetzel jun. and S. Rodman (*Iron Steel Eng.*, 1959, **36**, Mar., 123–132) Laboratory tests indicate that, for a given amount of lubricant, increasing its viscosity up to a certain value reduces rolling loads. Water-soluble chemicals and mixtures were found to be the best lubricants.

Experience in and knowledge gained from the operation of a wide hot strip mill and a cold strip mill E. A. Spenlé (**Stahl Eisen*, 1959, **79**, May 14, 683–693) The author describes the rolling mill practice applied to a wide hot strip mill and a cold strip mill at the August Thyssen-Hütte, Duisburg-Hamborn. Besides the technical description economic aspects are discussed. An appraisal of different rolling mill practices, e.g. advantages and shortcomings of reversing mills as compared with four-stand tandem mills is included.—T.G.

Some experiments on cold strip rolling H. Takahashi and S. Miyoshi (*J.Mech. Lab.*, 1959, **13**, Jan., 1–11) Roll loads and torques in the rolling of annealed and prestrained mild steel strips at various reductions were measured and calculated by two methods. The question of optimum pass schedule is considered. Tensile tests are also described.

How theory can help the cold roller E. L. Morgan (*Sheet Met. Ind.*, 1959, **36**, Jan., 53–61) A lecture. The theory of cold rolling is propounded, with a note on automation.

Cold rolling of steel strip G. A. Finch (*Sheet Met. Ind.*, 1959, **36**, Mar., 211–222) A lecture. Types of steel, strip properties, pickling and other pre-treatments, roll size and contour, bearings, reductions, heat treatment and furnaces, skin passing or temper rolling, control and automation are very briefly reviewed.

New design of driver back-up rolls for cold-rolling mills V. Wolpert (*Sheet Met. Ind.*, 1959, **36**, Mar., 201) A brief account of the Schloemann MKW design.

A Russian fine wire rolling mill O. Tedder (*Iron Steel*, 1959, **32**, Feb., 44) A description is given of an improved 12-stand fine wire rolling mill designed by the Central Scientific Research Institute of the Soviet Ministry of Machine Construction.

Trends and developments in electrical automation systems for steel plant processes W. E. Millar (*Blast Furn. Steel Plant.*, 1959, **47**, Jan., 64–71) Subjects dealt with include the redesigning of main drive motors to facilitate maintenance, various types of control equipment, and the packaging of heavy duty equipment.

Direct-current motors for rolling-mill auxiliary drives and their control H. Drück and H. E. von Knobloch (*Stahl Eisen*, 1959, **79**, June 11, 866–873) The advantages of d.c. motors as compared with three-phase a.c. motors for this purpose are stressed. A number of modern designs of d.c. motors, their performance and control and control equipment are described.—T.G.

Ingot delivery from soaking pits to the blooming-mill roller table Committee for Inventions and Discoveries (*Stal'*, 1959, (2), 149–150) An installation is described comprising a conventional ingot car and another of special design, which is shown, to convey the ingots from the nearest group of soaking pits and from the intermediate roller table to the ingot receiving table of the mill. This dispenses with the use of a crane and breaks the bottleneck often occurring at this point.

Development of the drives and other electrical machinery in rolling mills W. Nürnberg (*Stahl Eisen*, 1959, **79**, May 14, 694–703) The use of rectifiers in rolling mills has changed the type of electrical drive and that of all auxiliary machines in the last few years exploring the way towards complete automation. The development is traced and control equipment and measuring apparatus reviewed and discussed.—T.G.

Steel strip shear and classifier drives at Velindre (*Engineer*, 1959, **207**, Feb. 20, 295–298) The automatic speed control system and electrical inspection equipment are described.

Rotary shears for longitudinal cutting I. G. Kulbatschny (*Mechanical Equipment for Rolling Mills*, 1954). The design of rotary shears and the commercially available types are considered. Power requirements, cutting pressures and work done are then treated and the necessary equations derived. The cases where one or both discs are driven, and multiple shear designs are discussed for both hot and cold mills.

Efficient handling of sheet G. Rich (*Sheet Met. Ind.*, 1959, **36**, Jan., 48–49, 52) An account of the new installations by the Rich Steel Co., Los Angeles, is given. Cranes, a roller conveyor and fork trucks are used.

Study of the flying micrometer. II T. Kinto (*Toyo Kohan*, 1954, **3**, May, 33–38) Quantitative details of the errors which can be caused in the readings (from expansion of gauge rolls, time lag of the temp. compensator, incorrect installation etc.) are given. A control scheme to eliminate these is described.—K.E.J.

MACHINERY AND SERVICES FOR IRON AND STEEL PLANT

Specifications for the design of ore-handling cranes: (a comparison between American and German specifications) O. Schindler (*Stahl Eisen*, 1959, **79**, July 23, 1083–1085) The differences in American and German specifications for the design basis of ore-handling cranes are pointed out and discussed.—T.G.

Cooling of crane cabins in hot workshops O. A. Kremirev and A. L. Satanovskii (*Stal'*, 1959, (3), 282–285) A system of air conditioning for the bridge crane operators at Dzerzhinsk is described. The air-water vaporization system was used.

Production cost of steam in waste-heat recovery plants P. V. Avan'ev (*Stal'*, 1959, (4), 370) A formula is proposed for saving of fuel where the unit is inside the HEP system. That of Karpitchin (*ibid.*, 1958, (3), 253–256) assumed separate heat supply.

Gasholders in steel works B. Oldrich (*Koh. Lapok*, 1959, **14**, Feb.–March, 100–103) The author reviews the construction, use, and cost of gas-holders in steel works.—P.K.

WELDING AND FLAME-CUTTING

Rumanian achievements in the field of welding St. Nadasan and A. Kottlar (*Soud. Techn. Connex.*, 1958, **12**, Nov.–Dec., 463–468) The development and present position in the field of welding in Rumania are reviewed, and some examples of welded structures in that country are given.

Welding of dissimilar metals by arc welding with coated electrodes J. Hinde (*Rev. Nickel*, 1958, **24**, (4), 79–89) Using this technique the welding together of various combinations of dissimilar metals, from nickel and stainless steels to mild steel, with different weld metals is studied, the article concluding with a reference to the welding of cast iron.

Metallurgy of heterogeneous joints. I. Steel-copper bond F. A. Calvo and A. Revuelta (*Cien. Tecn. Solda*, 1959, **9**, Feb., 1·1–1·15) Experiments are described and illustrated by micrographs which show that an Fe-Cu bond with good mechanical properties is possible. The properties of welded joints of the two metals are examined (13 refs.).

Niobium in stainless steel weld metal G. G. Mukhin and N. Ya. Palch'uk (*Brit. Weld. J.*, 1959, **6**, Feb., 82–86; from *Avtom. Svarka*, 1957, (2), 1–10) The effect of up to 3% Nb on structure and mechanical properties of welds in 18/8 type steels is described. After heat-treatment at 850° or 650°C, a previously unreported phase (the N-phase) was detected in addition to Fe_2Nb_2 and $Fe_4Nb_6)Si_3$ which form during welding. The phase is similar in structure to the chi-phase in 18/8 steels containing Mo.—A.D.H.

The effect of the kind of current on the interaction between slag and metal in electro-slag welding Yu. N. Gotal'skii (*Avtom. Svarka*, 1955, **8**, (5), 47–49) In d.c. welding there is more transfer of Si from slag to metal than in a.c. welding and the observations support the view that the greater transfer in a.c. electroslag as compared with ordinary arc welding is an electrolytic effect.

Butt welding of high carbon and alloy steel wires A. T. Galaktionov and A. A. Fofanov (*Stal'*, 1959, (4), 374–377) Frequent breaks of butt welds in wire drawing led to investigations to lay down satisfactory welding conditions and to the design of an automatic flash welding machine which also removed heat burrs and applied heat treatment. Defects in the welds were identified, especially oxide inclusions, and structures are shown.

Control of melting rate and metal transfer in gas-shielded metal-arc welding. Part II. Control of metal transfer A. Lesnewich (*Weld. J.*, 1958, **37**, Sept., 418s–425s) Axial-spray, rotating-spray, and globular methods of metal transfer in gas-shielded metal arcs are compared, and reasons for preferring the first method are given and discussed.

The cast and welded stern-post of an atomic icebreaker P. A. Orekhov (*Svarochnoe Proizvodstvo*, 1959, (1), 40–41) The weldment, total weight 83 t, dimensions 19·2 × 11·0 m, consists of 12 separate castings to facilitate rail transport. The article not only describes preliminary experiments leading to, and the actual welding, of the stern-post, but also the heat treatment of the castings and the making good of defects before despatch from the foundry.

Three new low-hydrogen iron-powder electrodes D. C. Smith and W. G. Rinehart (*Met. Prog.*, 1959, **75**, Feb., 102–107) Three new electrodes have been developed for high-strength weldments of steels 4131, 4140, and 4340 as used in the aircraft industry. Tests show that the weld metal matches hardness and tensile strength of the base at tempering temperatures between 450 and 1250°F.—T.G.

Alumoweld wire, a new aluminium coated steel wire with a thick coating L. C. Whitney (*Wire Wire Prod.*, 1958, **33**, Nov., 1362–1364, 1413) An account is given of the development to pilot plant scale of a process for producing Al-coated wires for transmission lines. Powder metallurgy techniques are used to give a bonded coating constituting 25% of the cross-sectional area.—A.G.

Influence of melting practice on the properties of Kh25N20 alloy M. I. Vinograd and B. E. Lyubinskii (*Stal'*, 1959, (5), 448–451) The alloy is used for welding stainless and heat-resisting steels. The ductility depends on its Si content but is sensitive to melting conditions.

The effect of moisture absorption and its retardation with unalloyed basic electrodes E. Kauhausen and S. Sadowski (*Schweissen Schneiden*, 1959, **11**, April, 115–120) The behaviour of electrode coatings in moist air is explained, and measures to retard the absorption of moisture by basic welding rods are described. Rods with water-repellant coatings keep better in storage and show improved welding properties. Subsequent drying before use is to be recommended however.

The weldability of various carbon and alloy steels C. Roques, H. Lejay, Ch. Dubois, and P. Bastien (*Rev. Mét.*, 1959, **56**, April, 331–350; discussion 350–358) It is pointed out that two factors must be present simultaneously in cases of brittle fracture near welded joints, the presence of high local stresses and the inability of the metal to deform plastically. In studying the second factor, the technique developed by Pellini and co-workers was used in tests on the parent metal. Results of impact tests on various grades of high-strength sheet, and investigations on the heat-affected zone adjacent to the weld are discussed (32 refs.).

Control of the weldability of steels (*Mét. Constr. Méc.*, 1959, **91**, April, 275–281) Subjects discussed include the definitions of weldability, its measurement by cracking and notch bar tests, and the behaviour of structural steels on welding.

Weldability of low alloy converter steels A. S. Astaf'ev (*Stal'*, 1959, (6), 553–560) O_2-blown steels from the naturally alloyed Orsk-Khalilovo pig-irons in the basic converter were examined for weldability by the fillet test. Five grades were tested after rolling into sheets. Tests for brittle tendencies were made, but, in general, satisfactory welds can be made. In some cases careful choice of the welding rod was necessary.

An investigation of lap seam welds in 17–7 PH stainless steel E. J. Funk and A. C. Willis (*Weld. J.*, 1958, **37,** Sept., 897–905) A method is described for measuring secondary current in a seam welder, and for calibrating the measuring equipment, and data on the seam welding of P.H. stainless steel sheet are given, with a discussion of defects found, and the detrimental effect on joint strength of elevated temperatures.

Effect of welding and stress relief on the parent plate J. E. Roberts (*Brit. Weld. J.*, 1956, **6,** Feb., 72–81) The mechanical properties of the heat-affected zone for mild steel, notch-ductile and low-alloy high-strength weldable steels are equal to those of the parent plate unless cracking or excessive hardening are absent. Brittle fracture is shown to depend on residual stresses and is less liable to occur in notch-ductile steels—A.D.H.

Research into the thermal processes during gas pressure welding of rods M. S. Nikitin (*Svarochnoe Proizbodstvo*, 1959, (1), 24–27) Coefficients were determined for the calculation of the thermal processes and compared with the results of experiments, and a comparison is made between the thermal efficiency of different torches. The method of calculation may be used for the calculation of the heating and cooling processes during gas pressure welding of rods in a ductile condition, and serve as a basis for choosing appropriate welding conditions, assessment of the processes of grain growth and structural transformations and also for the choice of design characteristics of multi-flame torches. Calculations of the heating of the rods with shielding of the weld on the basis of a fixed surface source, the heat flux of which is distributed evenly over the periphery of the rods and normally along the generating line, satisfactorily agrees with experimental results. The experiments show that the intensity of the heat exchange between the flame and the surface of the rods in the first stage of heating is 8–10 times greater than in the second stage.

Joining aluminium to stainless steel M. C. Smith and D. D. Rabb (*NBS*–3522, 1955, Mar., pp.19; from *US Govt. Rep.* 1958, **30,** Nov. 14, 471. No abstract).

Air-hardening, high-strength steel is easily welded (*Mat. Design Eng.*, 1958, **48,** Dec., 124–125) A new ultra-high-strength alloy steel called X200 that can be air-hardened and tempered to a UTS of 280000 psi has been developed by US Steel Corp. It contains: C 0·41–0·46, Mn 0·75–1·00, P ≯ 0·025, S ≯ 0·025, Si 1·40–1·75, Cr 1·90–2·24, Mo 0·45–0·60, and V 0·03–0·08%. Tensile properties for elevated temperatures are listed from 400–1200°F. The steel is easily welded by both metallic and inert gas arc welding.—T.G.

Recent developments in weld electrodes. I W. P. Campbell (*Can. Metalw.*, 1959, **22,** Mar., 40–44) The author discusses the development of low-hydrogen welding electrodes and outlines their advantages and chief applications The addition of iron powder to the electrode coating is also considered, and the mechanism by which the iron powder influences the electrode performance is described.—G.F.

Most advanced electrodes (*Engineer Foundryman*, 1958, **24,** Dec., 43–45) A description is given of the new electrode plant of Thermal Welding Products, Benoni. Special features include a patent extrusion feed, magnetic suspension of electrodes during drying and electronic plant control.—A.G.

Some facts about iron powder electrodes A. B. Fieldhouse (*Weld. Met. Fabr.*, 1959, **27,** Feb., 61–70) The development of electrodes coated with mixtures containing iron powder is reviewed and the types now available, their characteristics, and some of their applications are given. Effects on performance are considered and ductile and tensile properties of the weld metal are tabulated, with notes on cooling rate, ageing, and welding current. The rutile and oxide-silicate types and the rutile-cellulose type are then separately discussed.

Alloy welding fluxes for low-alloy steels, stainless steels and hard surfacing R. A. Wilson (*Weld. J.*, 1959, **38,** Jan., 20–27) Compounded alloy fluxes can be made up from four primary types (Cr, Mo, V, and Ni flux) and a neutral flux. The primary fluxes are blended with the neutral flux to give the following percentages of maximum alloy content of any one element in the weld deposit: Cr 8·7, Mo 6·2, V 2·2, and Ni 11%. Applications of the flux are described.

Interaction between slag and metal in electroslag welding Yu. N. Gotal'skii (*Avtom. Svarka*, 1954, **7,** (5), 38–43) The process is described and Si and Mn transfer to metal as a function of flux basicity (Mn increases and Si decreases) and the occurrence of an electrolytic transfer of foreign elements to the weld metal at the electrode tip is noted and the mechanism is discussed.

Effects of preheating, thermal stress relief and electrode type on notch toughness L. J. McGeady (*Weld. J.*, 1958, **37,** Dec., 543s–553s) A study was made to determine what comparative benefits in notch toughness of weldments may be realized through use of pre-heating for welding, as against thermal stress relief, or by changing from type E6010 to type E6016 electrode. The results carried out on A–201 and A–212 steel plate, 1½ in. thick are presented in many graphs and tables and discussed in detail.—T.G.

Postheat treating weldments with an exothermic material M. F. Sheely and B. L. Lacey (*Weld. J.*, 1958, **37,** Dec., 554s–557s) The exothermic material consists of Al powder, metal oxides, refractory materials and binders. The results of the study show that 5%Cr–0·5%Mo wrought pipe weldments can be successfully postheat-treated with such an exothermic material. Metallurgical examination and physical tests revealed no detrimental effects caused by this treatment.—T.G.

The weld heat-affected zone E. F. Nippes (*Weld. J.*, 1959, **38,** Jan., 1s–18s) The 1958 Adams Lecture. Effect of weld thermal cycles on the microstructure and mechanical behaviour of the base metal in the heat-affected zone is described and the following topics discussed: prediction of arc-welding conditions; weld thermal cycles; knife-line attack in austenitic stainless steels; hot ductility of high-temperature alloys; studies of the heat-affected zone of T–1 steel; prediction of weld heat-affected-zone microstructures; and development of a high-speed dilatometer.

Phase analysis of resistance welded joints in unalloyed and low-alloy carbon steels D. Hrivnak and I. Hrivnak (*Brit. Weld. J.*, 1959, **6,** May, 229–237; from *Hutnicke Listy*, 1958, **13,** (3), 233–241).

Brazing – a practical and versatile art H. Thomasson (*Canad. Metalw.*, 1958, **21,** Dec., 30–32) Brazing has been improved greatly by modern methods of heating such as h.f. induction, furnace, and resistance heating. The useful fields of applications of these methods are briefly outlined.—T.G.

Vacuum brazing furnace design G. J. Crites (*Ind. Heat.*, 1959, **26,** Mar., 462–470, 480–486, 494) The author first discusses the essential atmosphere, temperature, and mechanical requirements of brazing equipment. He then considers the design of vacuum brazing furnaces, dealing particularly with the vacuum and electrical requirements. Two examples illustrating the type of calculation necessary for element design are included.—G.F.

Further evaluation of Ni–Cr–B and Au–18Ni brazing alloys W. H. Chang (*Weld. J.*, 1958, **37,** Dec., 535s–542s) The tensile and impact properties of AISI 347 and AISI 410 butt joints brazed with Ni–Cr–B alloy and with the Au–18Ni alloy are evaluated. Data in the form of tables and graphs are presented to show the changes of tensile and impact strength as affected by temperature and/or joint clearance for temperatures between room temperature and 1200°F. Some data on the 1500°F oxidation resistance of the brazed joints are included.—T.G.

Bright heat treating stainless steel parts at Specialty Steel Treating, Inc (*Ind. Heat.*, 1959, **26,** Mar., 630–632) A hump-type 20 in. mesh-belt electric furnace is used by Specialty Steel Treating Inc. for continuous bright brazing of stainless steel assemblies without flux, and for bright annealing and hardening of metal parts which must be finished to close tolerances. Details of the installation are given.—G.F.

One temperature for successive brazes G. D. Cremer and R. S. Mueller (*Prod. Eng.*, 1958, **29,** Dec. 8, 84–86) Use of nickel alloys having raised remelting temperatures along with careful design allows complex multiple brazing schemes to be carried out.

High-temperature brazing alloy – base metal wetting reactions W. Feduska (*Weld. J.*, 1959, **38,** Mar., 122s–131s) Five high-temperature metals (3 iron-base) and 6 brazing alloys were tested for 118 combinations of one or the other and the results are tabulated. In general, wettability decreased with rise of temperature and this is attributed to reaction between the components. Vacuum and H_2 and He atmospheres were used. Wettability in a vacuum was usually greatest.

Predicting gap change reduces trial runs in brazing dissimilar metal joints D. C. Herrschaft (*Weld. J.*, 1959, **38,** Mar., 232–235) A mathematical investigation and the resulting nomograph are presented to predict joint clearances on raising to brazing temperature. It is not claimed entirely to eliminate trial runs.

Study on the soldering of tinplate H. Ito and Y. Suginohara (*Toyo Kohan*, 1955, **4,** Dec., 1–6) Hot-dipped and electroplated tin plates were soldered under controlled conditions (given). Fluxes containing NH_4Cl or aniline salt give good soldering. Solders containing various amounts of tin produce equivalent results at 100°C above the m.p. Heavier coatings give better results, and the chemical treatment of the surface makes no difference.

A study on the soldering of electro-tinplate H. Morimoto and I. Tanaka (*Toyo Kohan*, 1955, **4,** Dec., 7–12) Solderability was evaluated by the capillary rise test. It is improved by using a high-lead (98%Pb) solder, by increasing the acidity of resin alcohol flux with 2–5% lactic acid or aniline salt, and by increasing wettability of the flux with 2–5% glycerine.—K.E.J.

A survey of the bonding of cermets to metals G. R. Van Houten (*Weld. J.*, 1958, **37,** Dec., 558s–569s) Metallizing history, joint design, joint materials, methods of wetting, methods of increasing braze strength and other pertinent topics are reviewed in this literature survey (168 refs.).—T.G.

A study of the deterioration of adhesives in metal bonds at high temperatures J. M. Black and R. F.. Blomquist (*WADC–TR–55–330; PB*–131500, 1955, pp.44; from *Nuclear Sci. Abs.*, 1959, **13,** Mar. 31, 502) Performance of phenol–formaldehyde–epoxy adhesives on stainless steel and Al with surface preparation, curing, ageing and atmospheric conditions was assessed.

4000-lb iron castings salvaged by compressed air-arc cutting M. G. Boyer (*Weld. J.*, 1959, **38,** Mar., 239–240) Sections were successfully cut away from castings 4 in. thick using air-arc cutting with a gouging torch after conventional methods had failed.

Simple pencil drawings guide automatic flame cutter E. T. Jones (*Iron Age*, 1959, **183,** Jan. 8, 59–61) An automatic flame cutting system is described in which the cutting torch is guided by an electronic tracer following ordinary pencil lines—A.G.

Paper template guides flame cut (*Iron Age*, 1959, **183,** Feb. 26, 89) A full-scale paper pattern is traced by a photoelectric head which actuates the flame cutter. Accuracy is ±1/32 in. when cutting shapes up to 1½ in. thick.—A.G.

Optical marking and automatic plate production W. R. Mellanby (*Trans. N.E. Coast Inst. Eng. Ship.*, 1959, Mar., advance copy, 247–284) A system of fabricating plates by the control of a flame cutter by means of a photographic negative from a drawing is described.

The hydrogen–nitrogen trifluoride torch H. H. Rogers (*Ind. Eng. Chem.*, 1959, **51,** Mar., 309–310) Cutting of cast iron and alloy and stainless steels, also welding and brazing processes, are outlined.

ERRATA *JISI*, 1959, **192,** Aug., p.402*a*, lines 22–23 from the bottom. For 'Both gave better results than the manual welds did' read 'Both gave good results, comparable with the manual welds'.

Ibid., line 15 from the bottom. For 'Heuber's'read 'Neuber's'.

MACHINING AND MACHINABILITY

Machinability study of a ceramic tool. III. Tool wear in ultra high speed cutting K. Yamada, N. Nakayama, H. Kajihara, S. Sakai and H. Mii (*Rep. Govt. Ind. Res. Inst. Nagoya*, 1959, **8,** Feb., 74–80) Cutting of steel at speeds up to 2 500 m/min with a carbide tool and at 1 200 m/min with a ceramic tool were examined. The former wore more rapidly, but the behaviour of the wear was nearly the same as in ordinary high-speed cutting. The ceramic tool showed little wear, and no crater wear on the top rake. Surface quality was fairly good.

Workability of cold-drawn steel on automatic lathes E. I. Fel'dshtein, B. I. Naumov, V. V. Konyashov and A. I. Ryazanov (*Vestnik Mashin*, 1959, (3), 57–61) A theoretical and practical analysis is given of the influence of various factors on the workability of these steels: cutting speed, cutting force and uniformity of the working surface.

Tool wear and machinability E. M. Trent (*J. Inst. Prod. Eng.*, 1959, **38,** Mar., 105–130) A microscopical study of the wear of carbide tools is described in terms of flank, cratering of rake face, build-up of rake surface and cutting edge, deformation of cutting edge, cracking of cutting edge and chipping or fracture due to impact. Illustrations of these types of wear are shown and related to cutting speed. Machining charts are produced for Nimonic and cast iron and for stainless and high-S steels. Flank wear is then examined and related to a number of factors, especiallly temperature distribution.

The effect of cutting fluids: effects on various work materials N. Shinozaki and H. Yoshikawa (*Rep. Inst. Phys. Chem. Res. Tokyo*, 1958, **34,** Nov., 365–373) [In Japanese].

On the action of metal cutting fluids at low speeds M. C. Shaw (*Wear*, 1959, **2,** Feb., 217–227) Fluids are classified as low speed, improving surface finish, and high speed, predominantly coolants. The low-speed type prevent welding by formation by chemical means of a solid layer on the chip. It is shown that they are required to form a relatively high shear strength layer and an explanation is suggested.

Sintered alumina cutting tools R. N. Cook (*Engineering Materials and Design*, 1958, **1,** Dec., 149–151) An account of properties and performance is given and recommendations for the use of ceramic tools and grinding wheels are made with comparisons with carbides.

Lubricant behaviour in concentrated contact systems — the castor oil–steel system F. W. Smith (*Wear*, 1958/59, **2,** May, 250–263).

Effect of phase transformations of steels on the wear of cemented-carbide cutting tools during machining H. Opitz and G. Ostermann (*Stahl Eisen*, 1959, **79,** Apr. 16, 514–522) X-ray analysis and electron-microscope studies of chips and of residues of the work piece on the cutting tool of cemented carbide showed that the steel to be cut undergoes a phase transformation from α to γ while gliding over the cutting tool. The austenite phase formed determines the reaction behaviour with the cutting tool and therefore the degree of wear of the latter. With increasing C content in the austenite the wear of the tool increases. It follows that wear of the tool tip will be least if the austenite formed can be kept very low. Trials to prepare steels that show a low-C austenite during cutting and consequently low cutting-tool wear were carried out.—T.G.

Ceramic and carbide tools tested on steels Production Engineering Research Association (*Metalw. Prod.*, 1959, **103,** Feb. 20, 320–324) Tests on En 28, 25 and 21 with eight makes of British and US ceramic tips are reported. The geometry of the tools is described and optimum cutting rates were measured. No recommendations are made but it is shown that such tools can be used successfully and may be superior for finish turning.

Machining hardened bearing races with cemented oxide tools H. J. Siekmann (*Machinery*, 1959, **94,** Mar. 4, 481–483) Tests leading to the development of machining methods for steels of 60–63 Rockwell C are outlined and the recommendations resulting are given.

Starting device reduces roll grinder size (*Metalw. Prodn.*, 1959, **103,** Mar. 27, 550) An auxiliary device incorporated in the headstock overcomes the high initial tongue and reduces size, weight and power consumption of roll grinding machines.

Metal smoothing B. M. Askinazi (*Mach. Design*, 1959, **31,** Feb. 5, 29–30, 32) An account of a Russian process in which a tool of TiC or similar material is forced against a revolving work-piece and a current of ~800 amps is passed through the contact.

Some electrical phenomena in metal cutting V. Šolaja and H. L. Hughes (*Wear*, 1958/59, **2,** May, 311–314) The thermo-e.m.f. is plotted against cutting speed for steel and other metals. It does not appear to give a reliable measure of wear.

Steel routing Ferrand Luttmer Ltd. (*Aircraft Prodn.*, 1959, **21,** Mar., 84–87) Profiling with WC-tipped tools cooled with CO_2 is described.

Electromachining speeds its attack H. L. Kee (*Prod. Eng.*, 1959, **30,** Mar. 2, 59–62) New Japanese electromachining equipment is described which has a novel impulse generator giving cutting speeds 40 times that of American models. The applications and limitations of the various methods of electromachining are discussed.—A.G.

System removes scrap with underfloor belts (*Iron Age*, 1959, **183,** Jan. 8, 70–71) The use is described of an underfloor scrap conveyor which collects scrap from a number of machine tools. Labour is saved and proper design is said to have resulted in very low maintenance costs.—A.G.

CLEANING AND PICKLING

Methods and chemicals commonly employed for the preparation of steel surfaces prior to painting J. H. Dudek (*IAAEJ*, 1959, **19,** Mar., 49–53) Solvent and alkali, steam and acid cleaning, pickling, and phosphate treatment are reviewed.

Flame scarfing stainless and heat-resistant steels D. I. Gololobov and B. M. Litvinov (*Stal'*, 1959, (2), 145–147) High Si and Cr steels in blooms and forged billets were scarfed experimentally, the tendency of such steels to crack after scarfing was verified. Al–Mn powder with or without Ca–Si added to the oxy-acetylene flame raises the temperature sufficiently. Comparisons with chipping and abrasive dressing were also made. An industrial process has been worked out with great saving of labour.

Cleaning and passivation of corrosion resisting steels L. Lowrey and J. Thompson (*Tech. Rep. NGF-T-28-57; NAVORD Rep. No. 5518; PB* 131964, pp. 25) Typical methods for the removal of scale, flux, slag and lubricant are surveyed and the function of passivation is considered. The rate of attack of HNO_3–HF pickling solutions and of HNO_3 passivating solutions was evaluated for AISI, 200, 300 and 400 types and the effect of chloride contaminants was noted. The rate was usually low ($0{\cdot}17$–$4{\cdot}51 \times 10^{-6}$ in./unit area/h). The effect of chloride was most marked in 400 type steels. The rate of attack of HNO_3–HF was greater ($32{\cdot}8$–$310{\cdot}2 \times 10^{-6}$ in./unit area/h) for 200 and 300 series steels and higher still (1904–6702×10^{-6}) for 400 series. Heat treatments producing carbides in 302 steel increased the rate of attack more than tenfold in HNO_3 and ~46 times in HNO_3–HF. Type 321 steel with similar heat treatment but without apparent carbide production showed very low rates of attack.

Factors influencing the rate-of-pickling test on tin-plate steel R. M. Hudson and G. L. Stragand (*Corrosion*, 1959, **15,** Mar., 135–140) Factors influencing the lag time test are identified and its complexity is shown. The high concentration of some elements on the surface before annealing and enrichment of the surface during that process are indicated as requiring study.

Wire prepared for drawing by mechanical descaling (*Steel*, 1959, **155,** Mar. 2, 116–117) After pilot plant experience a Cleveland firm has adopted mechanical descaling in preference to pickling. Among other advantages the minutely cupped surface holds lubricant and facilitates drawing.—A.G.

Preliminary study of ultrasonic descaling Aeroprojects Inc. (*NYO*-7923, pp. 14; from *US Govt. Res. Rep.*, 1958, **30,** Nov. 14, 472, No abstract).

Some tips on barrel finishing B. A. Farmer (*Prec. Met. Mold.*, 1959, **17,** Mar., 51–53) In a series of questions and answers, the author gives some general hints on the efficient operation of the barrel-finishing process. Typical parts are illustrated and the relative costs of barrel-finishing and hand-finishing are compared.—G.F.

Savings with a new type graphite heat-exchanger in steel pickling plant B. A. Garman, A. Hilliard and N. H. Riches (*Brit. Chem. Engineering*, 1959, July, preprint, pp. 5) An account of the use of a Polybloc installation for heating steel pickle liquor at Wednesbury is given. The prevention of deposition in the plant is discussed and costs are considered.

Some recent developments in graphite heat-exchangers and similar equipment A. Hilliard (*Industrial Carbon and Graphite*, 1958, *reprint*, 605–617) The design and properties of graphite block heat exchangers are outlined.

Considerations on the design of graphite heat-exchangers A. Hilliard (*Brit. Chem. Engineering*, 1959, March, reprint, pp. 6) The development and construction of the Polybloc graphite heat exchanger are described and its flow and pressure-drop characteristics and heat exchange capacity are shown.

Studies on the waste liquor from plants. I. On the harmful components and the water pollution of the foul water. II. A new disposal method of the acid-pickling waste liquor K. Sivazuki and S. Hanawa (*Toyo Kohan*, 1953, Dec., 56–60; 61–65) [In Japanese] I. The chief harmful constituents are ferrous sulphate and sulphuric acid (contents, pH etc. given) from acid pickling. Dilution over twenty times makes the water harmless to aquatic life. II. A treatment is proposed whereby conc. H_2SO_4 is added to the waste to ppt. $FeSO_4$, and the solution is then diluted for use in pickling. Optimum conditions are established. Recoveries are 50% $FeSO_4$ and 60% H_2SO_4.

A review of modern methods available for the disposal of finishing trade effluents (*Prod. Fin.*, 1959, **12,** Mar., 64–71) From information supplied by manufacturers of equipment. The account is intended to supplement the recent series on legal requirements.

In the new towns: a review of Local Authority bye-laws on finishing trade effluents Lord Meston (*Prod. Fin.*, 1959, **12,** Apr., 54–60).

PROTECTIVE COATINGS

Properties and uses of electroplates (*Mat. Design Eng.*, 1959, **49,** Feb., 121) A table of physical properties, corrosion resistance and soldering properties with an indication of uses is presented for 35 metals and alloys.

Reference index of the current protective coatings specifications (*PB* 151166, [1959], pp.159) A list of US Govt. specifications for plating, corrosion resistance, finishes of various kinds, trade names, etc. for metals and non-metals.

Science for electroplaters. XXXVI. Organic chemistry L. Serota (*Met. Fin.*, 1958, **56,** May, 93–96; June, 76–77; July, 70–73) Elementary ideas of structure and simple reactions of hydrocarbons and alcohols and an outline of polymerization reactions are given. Aldehydes and ketones are also mentioned. **XXXIX.** (Aug., 73–75, 81) Organic acids are described. **XL.** (Sept., 67–70) Oxalic, succinic, tartaric and citric acids and their uses in plating are described in an elementary way. **XLI. Aminoacids** (Oct., 74–76; Nov., 73–74) Sulphonic acids are also considered with examples of Cu baths and of cresolsulphonates in tin baths. **XLII. Amines** (Dec., 66–69) Various uses of

amines in plating are noted. The ethanolamines are included. **XLIII. Diamines** (1959, **57,** Jan., 62–64) Ethylenediamine and its formal derivatives and their use as chelating agents are described, with the effects of pH and their use in analysis, such as the determination of Mg with EDTA. **XLIV. Amides** (Feb., 71–73) Uses of formamide in electrodeposition, of sulphonamides, urea and thiourea are outlined. **XLV. Sulphamic acid** (Mar., 67–69) Uses for Pb, Ni and In and for anodizing are reviewed. **XLVI. Organic salts** (Apr., 71–74, 76) Formates, acetates, tartrates, laurates, etc. are reviewed as plating bath constituents. **XLVII. Esters** (May, 72–73, 76) Uses of sulphated alcohols and of polymethyl methacrylate are noted, the latter as insulators and coatings.

Stripping metallic coatings J. B. Mohler (*Met. Fin.*, 1958, **56,** Dec., 60–63) After discussing general stripping methods the author deals with quantitative stripping, *inter alia*, brass, Cd, Cu, Cr, Cr–Ni–Cu, Au, Pb, Ni, black oxide coatings, phosphate coatings, Pt, Ag, Sn, Sn–Zn alloy, and Zn from steel.—T.G.

Plating on aluminium using an iron interlayer D. S. Tandon and T. Banerjee (*Trans. Indian Inst. Met.*, 1959, **12,** Mar.) **Part I. Application of an iron inter-layer with subsequent flash-plating of copper or brass** (37–44). **Part II. Application of an iron inter-layer without subsequent flash-plating of copper or brass** (45–53). **Part III. Use of iron inter-layer deposited from ferric chloride solution at temperatures lower than 95°C, and without flash-plating of copper or brass** (55–67).

Fire hazards in metal finishing D. J. Fishlock (*Electropl. Met. Fin.*, 1959, **12,** Mar., 85–92) Extinguishing media are also reviewed.

Plating waste disposal W. Mikos and A. Szkudlapski (*Met. Fin.*, 1959, **57,** Feb., 61–64) A system for cyanide and Cr disposal is described. Cyanide is oxidized with chlorine and chromate is reduced to chromium sulphate with SO_2 and precipitated with Na_2CO_3 NaOH and lime.

Variations in the design of plating waste treat systems R. Dvorin (*Plating*, 1958, **45,** Aug., 827–831) Variations in plant design for the treatment of plating wastes according to the quantities and types of waste discharged are discussed. The clarification unit, which is described and illustrated, is the same for all operations. It is very practical and easy to operate.—T.G.

Five years of ion exchange: User's report on service experience in plating department chemical waste treatment S. Rothstein (*Plating*, 1958, **45,** Aug., 835–841) A Permutit ion-exchange plant for regeneration and removal of chromic acid from plating waste solutions is described. By purifying the chromic acid with the aid of ion exchangers, substantial savings have been achieved.—T.G.

The conservation approach to industrial waste control D. Milne (*Plating*, 1958, **45,** Aug., 842–846) Ten general steps which may be taken by manufacturing plants to cut down the volume of waste materials leaving their plants and to conserve the sometimes valuable chemicals lost in waste waters are recommended.—T.G.

How Trans World Airlines treats plating shop wastes R. L. Garrett, R. C. Garland, and T. Sawyer jun. (*Plating*, 1958, **45,** Aug., 847–850) A semi-automatic oxidation and reduction plant for the treatment of cyanide and chromium wastes is described.—T.G.

Recent developments in chromium plating D. E. Weimer (*Met. Fin. J.*, 1959, **5,** Mar., 89–97) The theory and practice of Cr plating are surveyed. The effect of heat treatment, crack formation, spray suppressants instead of fume extraction, use of high-speed solutions, self-regulation of catalysts and crack-free Cr production are considered (14 refs.).

Has chromium plating deteriorated? R. Silman (*Prod. Fin.*, 1959, **12,** Feb., 65–72) A discussion of Ni–Cr plated automobile parts with considerable data on marine atmosphere exposure. It is regarded as unlikely that present-day plating is any worse than pre-war.

The mechanism of the electrodeposition of chromium A. T. Vagramyan and D. N. Usachev (*Zhur. Fiz. Khim.*, 1958, **32,** (8), 1900–1906) The reduction process in chromic acid shows that it is necessary to delimit sharply two potential regions within which the reaction proceeds at the cathode. The polarization curve may be divided into two sections, one up to 0·7 V potential and the remaining section for a more negative potential up to 1 V. The first section corresponds to the reaction $Cr^{6+} \rightarrow Cr^{3+}$. With a potential above 1 V, three simultaneous reactions occur at the electrode: $Cr^{6+} + 6e \rightarrow Cr^{2}$; $Cr^{6+} + 3e \rightarrow Cr^{3+}$; $2H^{+} + 2e \rightarrow H_2$. The reduction of hexavalent to tervalent chromium in the presence of sulphuric acid has been shown to be due to atomic hydrogen.

The structure and mechanical properties of electrodeposited chromium C. P. Brittain (*Cambridge Abstracts of Dissertations*, 1956–1957 (1959) 180–181) Six types were obtained by varying the temperature from 45° to 85°C and these were annealed at 300–1050°C for from 3·6 sec to 100 h. Complex changes were observed in the low-temperature deposits and correlated with changes in hardness. These changes did not occur in the high temperature deposits, though softening occurred. Microcompression tests revealed a linear relation between yield stress and hardness. Crack formation related to H_2 evolution was also observed directly.

Structure and growth of iron and chromium electrodeposits on copper single-crystal faces A. K. N. Reddy and H. Wilman (*Trans. Inst. Met. Fin.*, 1959, **36,** Spring, 97–106) Electron diffraction studies were made. Four main stages of growth are distinguished characterized by the type of crystal orientation. Temperature effects and co-deposition of $Fe(OH)_2$ were also noted.

Automatic plant for hard chromium plating piston rings H. C. Hickman (*Electropl. Met. Fin.*, 1959, **12,** Feb., 55, 57) An Efco–Udylite plant erected in France is briefly described.

Composition and application of anodes D. J. Fishlock (*Met. Fin.*, 1959, **57,** Mar., 55–59) Inert anodes for Cr and Ni plating and for various other metals are reviewed (22 refs.).

Modified Hull cell J. P. Branciaroli (*Plating*, 1959, **46,** Mar., 257–260) A description of the new design and a comparison with the conventional type are given. It is especially designed for testing Cr baths.

Hard nickel plating A. J. Steiger (*Met. Ind.*, 1959, **94,** Mar. 6, 189–190) A review of Russian work from *Priborostroienie* claiming the use of an oxalic acid bath and giving twice the hardness of the normal sulphate bath with more rapid deposition. Heat-treatment at 300° still further increases hardness, approximating to that of Cr.

Effects of impurities in a bright nickel bath on the covering power of a chromium bath R. H. Rousselot and G. E. Rousselot (*Met. Fin.*, 1958, **56,** Dec., 46–50) The authors point out that the covering power is a function not only of the independent variables of the Cr bath, but also of the basis metal and its preparation which, in the present instance, is the underlying Ni plate. The sources of the impurities are, *inter alia*, the dissolution in the bath of the parts plated, i.e. steel and other metals.—T.G.

Barrel unit and sulphamate bath make nickel plate stress-free (*Steel*, 1959, **144,** Feb. 23, 98–100) Advantages claimed for the barrel plating process using a nickel sulphamate bath include a stress-free deposit free from impurities. Controlled strength hardness and brightness and ease of control of bath composition. Some applications are suggested.

The properties of bright nickel electrodeposits in relation to the period of service of the plating bath. III. Composition and microstructure J. Edwards (*Trans. Inst. Met. Fin.*, 1959, **36,** Spring, 86–92) Two proprietary solutions have been analysed for C, O, H and N. The amount of organic material incorporated in the deposits tended to increase with length of service of the bath. It appeared that additions of anti-stress agent which lowered stress and raised ductility also reduced the amount of organic matter included.

Smoothing the surfaces of ferrous metals by copper and nickel electroplating N. A. Solov'ev (*Vestnik Mashin*, 1959, (2), 69–71) The main factors considered are: chemical composition and concentration of electrolytes, conditions of the operation, and dimensions, form and depth of layer and the effect of their interaction.

High temperature coatings for chromium hot work tool steels E. B. Norris (*WADC Tech. Rep.* 58-269; *ASTIA Document No.* 203121; *PB* 151423, 1958, Oct., pp.84) A 5% Cr steel was used to test various anticorrosive treatments for high temperature use. Coatings were applied by plating, dipping or spray. The effects on tensile, stress-rupture and fatigue properties at ordinary and elevated temperatures were also studied. The resistance of the coatings to wear and thermal shock was investigated. Ni–Zn, Al, and alumicoat and Ni were most successful against corrosion. Only Al–silicone paint did not reduce fatigue strength. Electroless Ni had the best abrasion resistance.

Galvanized sheet for outdoor applications M. H. Davies (*Met. Fin. J.*, 1959, **5,** Mar., 98–100) Standards are noted and ASTM exposure tests are summarized. Notes on painting are included.

The EMF, and electrode potentials of tin and iron in systems with tin-containing flux-electrodes A. I. Vitkin (*Zhur. Fiz. Khim.*, 1958, **32,** (7), 1612–1617) By means of radioactive ^{121}Sn and analytical methods, tin deposition from flux solutions and fused melts on sheet iron has been studied. For this purpose the e.m.f and electrode potentials have been measured and it has been shown that the flux/iron/tin system is the anode and the iron plate on which tin was deposited from the electrolyte, the cathode. In molten fluxes, tin deposition is more rapid than from solution.

On the electrolytic tinning line K. Yokoyama (*Toyo Kohan*, 1954, **3,** May, 1–13) A review, covering layouts of acid and alkali lines, some data on the world's plants, and details of the individual items of equipment associated with electrolytic lines.—K.E.J.

On linear defects on the surface of tin plate T. Yasunaga and A. Tada (*Toyo Kohan*, 1954, **3,** May, 39–44) Causes of linear defects, causing 10% waste, were sought in differences between the top and bottom surfaces of hot-rolled tin bars and in steel melting-shop practice.—

Study on the iron-tin alloy layer of tinplate T. Oyama (*Toyo Kohan*, 1955, **4,** Dec., 13–22) Various aspects of the formation of white and black crystalline aggregates, particularly the former, are discussed. The white structure appears to be formed by the reaction between molten tin and sheet which has already received some tin from the flux by thermal or electrochemical reaction.—K.E.J.

On the electromagnetic tin coating gauge K. Takemoto and M. Matsubara (*Toyo Kohan*, 1953, Dec., 47–51) A gauge operating on the principle of variation of induced voltage in a secondary coil with thickness of tin coating can gauge the thickness of 0·30–3·00 lb/basis box coatings within ± 5%.—K.E.J.

On the deterioration of tinning oil. II. Investigation of palm oil substitutes and additives Y. Kitamura (*Toyo Kohan*, 1953, Dec., 37–46) Various oils, with or without additives, are heated in contact with tin, and the rise of viscosity with time is studied. The rise is lowest with palmitodisterin, but this is inferior to palm oil because of fluxing and dewetting ability. 30% of spermaceti added to palm oil reduces the viscosity rise but does not lead to good fluxing. The best results are obtained by adding 1% of the antioxidant Nocrac C (made by Ouchi Shinko Kagaku K.K.) to palm oil (15 refs).—K.E.J.

Study of the flux in hot dip tinning I. Yano and O. Yanabu (*Toyo Kohan*, 1953, June, 46–53) $AlCl_3$ added to $ZnCl_2$ flux gives greater activity than HCl, NH_4Cl, $SnCl_2$ or NaCl. Flux containing HCl is also more active than the normal. The volatility of $AlCl_3$ and HCl causes the activity of these fluxes to fall rapidly at 200°C, but after 8 h the activities are still higher than that of fresh normal flux. Greyness decreases with a flux temp. of 180–200°C, mottle patterns disappear on adding $SnCl_2$ to the flux, and the amount of alloyed tin decreases with rising temp. of Sn and flux and increasing tinning speed.—K.E.J.

The relation of tin coating weight and deformation degree to the porosity of tin-plate M. Hanada (*Toyo Kohan*, 1953, June, 6–14)

The number of pores per 100 cm² falls from 600 to 200 as the coating thickness increases from 1·20 to 2·30 lb/basis box, and thereafter more slowly. The number rises from 1000 to 5000 as the degree of deformation increases from 10 to 30%, with an average wt. of 1·50 lb/basis box. Pores are mainly associated with bad surfaces of the base plate, and with grease marks, scruff bands, transverse ripples and scratches in the tinned surface.—K.E.J.

A method of sampling inspection by variables on Erichsen testing Y. Yoshimura, T. Torihata, and S. Asada (*Toyo Kohan*, 1953, June, 15–18) A statistical scheme is devised for the acceptance of lots of tinplate on the basis of a reduced number of Erichsen tests.—K.E.J.

An electrical method of measuring carburized case depth and thickness of non-magnetic electrodeposited coatings T. I. Pavlov (*Zavod. Lab.*, 1957, **23,** (1), 67–69) A four-arm bridge arrangement with coils in two arms with U-shaped iron cores, one being the probe, and in the other two arms, half-windings of a differential choke coil is used. Calibration and use to obtain case depth is described. It also serves without modification for measurement of non-magnetic coatings.

Effect of biologically polluted waters in electrodeposition K. Sommer (*Electropl. Met. Fin.*, 1959, **12,** Mar., 105; from *Metallwaren-Industrie und Galvanotechnik*, 1958, **49,** (8), 351) Defects appearing in bright Ni plating from micro-organisms and plant fibres in water are described.

Electrodeposition of high-purity chromium F. E. Block, P. C. Good, and G. Asai (*J. Electrochem. Soc.*, 1959, **106,** Jan., 43–47) Cr with 0·005%O, < 0·002%N and only traces of other metals was deposited from CrO_3 baths at elevated (85–90°C) temperatures. After arc melting with consumable electrodes the product could be hot-worked to rod and drawn to wire that was ductile at ordinary temperature.

Chromium plating in relation to the corrosion resistance of nickel-chromium deposits A. Smart (*Electropl. Met. Fin.*, 1959, **12,** Jan., 3–10) Requirements for satisfactory outside exposure resistance are set out, it being shown that the quality and thickness of the Cr is the controlling factor. Deposits of ~ 40 microin. on 1 mil Ni are found to be satisfactory.

Purification of chromic acid solutions by means of cation exchangers G. Gabrielson (*Met. Fin. J.*, 1959, **5,** Jan., 19–21) The use of sulphonated resins is described, especially for Al removal.

Recent progress in the technique of nickel plating L. Ades (*Corros. Anticorros.*, 1958, **6,** Dec., 440–443) Recent improvements in the technique of Ni plating and in the quality of the deposit obtained are described – ultra rapid baths, chelation, the use of ultrasonics, etc.

The chemistry of bright nickel plating solutions F. B. Saubestre (*Plating*, 1958, **45,** Dec., 1219–1227) The chemical groupings characteristic of brighteners are listed. The reactions of brightness and their oxidation-reduction products with nickel are discussed in relation to the effect on nickel plating. Finally the principles of compounding brighteners and their effects on bright nickel deposits are summarized.—A. G.

The structure of electrodeposited nickel B. C. Banerjee and A. Goswami (*J. Electrochem. Soc.*, 1959, **106,** Jan., 20–23) An electron-diffraction study of crystal structure, orientation and mode of growth of Ni deposits from SO_4–BO_3–Cl and Cl–BO_3 baths has been made. Change of pH, temp., concentration, c.d., rate of stirring and of additions of $H_3(O_2)$, $Ni(NO_3)_2$ and NaCl were investigated. Various preferred orientations appeared depending on bath conditions and these are discussed and correlated with cathodic growth processes.

Hard nickel plating in Russia A. J. Steiger (*Met. Fin.*, 1959, **57,** Jan., 52–53) A brief account is given of the electroplating process developed in Russia for producing hard Ni deposits, using a nickel sulphate-ammonium oxalate bath. The process was developed to obtain a good wear-resistant finish on profiled parts installed in electronic and electromechanical computers.

Effects of impurities in a bright nickel bath on the covering power of a chromium bath R. H. Rousselot and G. E. Rousselot (*Met. Fin.*, 1959, **57,** Jan., 58–60) The effects of Sn, Cd, and Mo present as impurities in a bright Ni bath on the covering power of a Cr bath are considered, and methods of removing impurities are examined.

Some properties and applications of chemically reduced nickel A. McL. Aitken (*Eletropl. Met. Fin.*, 1958, **11,** Dec., 427–431) The Kanigen process is reviewed, the significance of H_2, the properties of the coating of Ni–P produced and its use on valve parts and other items are described.

What electroless nickel can do for you R. J. Girard (*Plating*,1958, **45,** Dec., 1234–1238) The process of chemically depositing an amorphous Ni coating is described. Advantages listed include uniformity of deposit, superior corrosion resistance and hardness, and savings in labour costs. Limitations are the brittle nature of the deposit and its poor adhesion to high carbon steels.—A. G.

Automatic bright zinc and cadmium plating for corrosion protection K. N. Sinclair (*Corros. Prev.*, 1959, **6,** Jan., 43–44) The merits of bright Zn and Cd plating, particularly when carried out in automatic plants, are emphasized.—T. G.

Modern methods of hot-dip tinning P. Dehais (*Corros. Anticorros.*, 1958, **6,** Dec., 451–456) Modern techniques applied to the hot tinning of steel and cast iron are outlined.

Continuous tinning lines: Foreword U. Miyazaki (*Toyo Kohan*, 1954, **3,** Dec., 1–10) [In Japanese] The composition of the various layers, inspection instruments, etc. are reviewed (14 refs).—K. E. J.

Testing of tinplates H. Morimoto (*Toyo Kohan*, 1952, Nov., 74–77) [In Japanese] A review, with 20 refs.—K. E. J.

Direct chloride tinning process has universal application E. S. Hedges (*Ind. Fin.*, 1959, **11,** Jan., 28–30) A description is given of the direct chloride tinning process developed at the Tin Research Institute; the process is compared with electroplating, and an example of its use in cast iron bearing shells is given.

Quality of PLASCO plate Y. Kitamura (*Toyo Kohan*, 1954, **3,** Dec., 42–60) [In Japanese] The variance of porosity of PLASCO plate is less than that of tinplate, and the stamping resistance is greater. The adherence of the film to a pickled base metal is good. Rusting is the same for specimens wrapped in paraffin and VPI paper, and the rate is slower for packaged than exposed samples.—K. E. J.

Aluminized steel, properties and uses. K. G. Coburn (*J. Met.*, 1959, **11,** Jan. 38–39) The structure produced by the Armco coating method is shown and adhesion, physical properties, weldability, corrosion resistance, and uses are briefly indicated.

Setting-up a metal-spraying workshop M. Lacorne (*Iron Steel*, 1958, **31,** Dec., 569–571) The author reports details of the layout and equipment of a metal-spraying shop for the treatment of coke wagons with Al (2 coats each 0·2 mm thick) and Zn (1 coat of 0·2 mm) after sand-blasting. Tests are being carried out to paint the sprayed coatings with an organic paint which on heating carbonizes and protects the metal coats. Emphasis is laid on maintaining the correct temperature and humidity in the workshop after sand-blasting the wagons in order to avoid oxide formation and so ensure positive adhesion of the metal coating.—T. G.

Sprayed coatings for ships. Use of zinc and aluminium for corrosion protection M. H. Clark (*Iron Steel*, 1959, **32,** Jan., 11–12) The results of trials of sprayed Zn or Al coatings on steel hulls of ships have proved satisfactory in reducing corrosion by electrolytic action. Several examples are quoted.

Corrosion protection: Aluminium-sprayed coatings at the Spanish National Steel Works S. Y. Scott (*Iron Steel*, 1958, **31,** Dec., 589–592) Based on the excellent results obtained with metal spraying of iron and steel works installations in England, the Spanish National Steelworks at Avilés is using this method of protection. The peculiarities and difficulties connected with the introduction of metal (Al) spraying and the experience gained are briefly reported.—T. G.

Metal spraying: Effect of a molybdenum deposit on adhesion and on fatigue of ferritic steels D. Birchon (*Metallurgia*, 1958, **58,** Dec., 273–285) It is known that a thin intermediate layer of Mo, although enhancing the adhesion of a subsequently sprayed metal coating on steel which has been finely machined and shot blasted, as well as deposition on a polished specimen lowers the fatigue strength of the finished component. The mechanism of this effect is discussed, and it is shown that controlled shot blasting, together with a Mo underlay, gives good adhesion combined with improved fatigue properties (16 refs).

Black oxide finish fights corrosion: Reduces friction on most metals B. U. Smith (*Western Metalw.*, 1959, **17,** Feb., 46–47) A process producing a black lustrous finish is outlined.

Recent developments in phosphate treatments H. A. Holden (*Product Fin.*, 1959, **12,** Jan., 76–79) A review, largely of proprietary processes.

The chemical surface treatment of strip steel for corrosion protection, for the improvement of the adherence of coatings and for the formation of insulating films W. Rausch (*Stahl Eisen*, 1959, **79,** Mar. 19, 349–358) The merits of phosphating and chromating are reviewed and methods for the two processes described, with modifications according to the purpose of the strip.—T.G.

Batch type aluminium coating of small steel parts R. F. Joy (*Wire Wire Prod.*, 1958, **33,** Nov., 1353–1356, 1408–1409) The operations involved, comprising precleaning, preheating, and fluxing, Al coating, removal of excess Al, quenching and inspection are described. The results of comparative corrosion tests at room temperature on Zn and Al coatings are given.

Aluminium coated steel wire products R. E. Griffiths (*Wire Wire Prod.*, 1958, **33,** Nov., 1358–1361) The metallurgy and corrosion resistance of hot dip Al coating on steel are discussed together with limited evaluation tests.—A.G.

High-strength steel can be cadmium-plated without embrittlement D. J. Cash and W. Scheuerman (*Met. Prog.*, 1959, **75,** Feb., 90–93) Cd is plated from a cyanide bath at 70 amp/ft² to give a porous plate which permits H_2 to diffuse out of the surface during subsequent heat-treatment. To control the absence of embrittlement a new sustained load specimen was designed so that it must fail if plated with the old standardized procedure. Production results are discussed in detail.—T.G.

Automatic barrel electroplating W. J. Rein (*Metalloberfläche*, 1959, **13,** Jan., 8–11) The operation of the automatic plant for Cd plating small parts at the Detroit works of Bellevue Plating Co. is described.

Further development of metal spraying technique (IV) H. Reininger (*Metalloberfläche*, 1959, **13,** Jan., 17–21) This section deals with technical equipment and preparation of the metal surface. (May, 147–149) Protective coatings against scaling, and the use of spraying for repairs are dealt with; the article concludes with references to methods of testing sprayed coatings (119 refs.).

Structure and protective action of sprayed metal coatings T. Kenderi (*Metalloberfläche*, 1959, **13,** May, 133–134) A paper contributed to the corrosion Conference in Budapest in September 1958. Eighteen factors determining the properties of a sprayed coating are enumerated and discussed.

Phosphating metal surfaces (*Mét. Constr. Méc.*, 1959, **91,** April, 285, 287) A brief outline is given of the composition of phosphate coatings used and their properties.

Study of phosphatation layers by X-ray diffraction J. Saison (*Compt. Rend.*, 1959, **248,** May 4, 2586–2588) The layers formed in a zinc phosphate bath are shown to be mixtures of hopeite and phosphophyllite with the same orientation on the c-axis.

Method of Parkerizing without sludge formation A. Z. Grebenshchikova and P. K. Stasevich (*Stal'*, 1959, (5), 443–444) A method for phosphating tubes before drawing, giving a good lubricating film, absence of corrosion, and absence of harmful lubrication products is described. The process takes 5–10 min at 65–75°C in a Zn phosphate solution containing HNO_3 and iron salts which form a Zn–Fe phosphate film without depositing sludge.

Enamel in 1958 H. J. Van Buren (*Chem. Weekbl.*, 1959, **55,** June 13, 276–283) [In Dutch] This is a review article opening with references to what has been published in Holland on the subject during 1958. It continues with similar work that has appeared in the international technical press during that year, notably in the USA, Germany, and England. The article carries a bibliography of 110 references concerning each of which the author makes brief comments.—F.R.H.

Vitreous enamelling of cast iron R. Märker (*Gjuteriet*, 1959, **49,** Feb., 33–34, 36, 38) The design, chemical composition, and structure of iron castings suitable for vitreous enamelling are discussed, and points to be observed in moulding practice are outlined.

The adherence of fritted and fused coatings to cast iron H. Hosse (*Giesserei*, 1959, **46,** March 26, 169) An abstract is given of an article by D. Kamran (*Mitt. Ver. Dtsch. Emailfach*, 1958, **6,** 85–91) showing the scaling of pearlitic cast iron in various atmospheres, and temperatures with and without enamel coatings.

Increased chemical resistance of enamel coatings I. F. Dubrov (*Stal'*, 1959, (6), 575) A note from the Ural Research Institute for Ferrous Metals. Electrical properties were studied in boiling HCl. Heat-treated siliceous coatings were more resistant.

Rust protection of steel structures and other metallic surfaces by paints and coatings (*Metalloberfläche*, 1959, **13,** Jan., 21) A list of subjects is given making up a coarse in the above-mentioned topics given at the Technischen Akademie Bergisch Land, Wuppertal-Elberfeld.

Corrosion protection by paints: a statistical review quoting as example some well-known steel structures K. A. van Oeteren-Panhäuser (*Werks. Korr.*, 1959, **10,** July, 442–445) The costs of corrosion protection of such structures as the Eiffel Tower and others are briefly discussed.—T.G.

CLAD SHEET AND HARD-FACING

Steel rolling mill rolls repaired by hard-facing V. K. Yatsura (*Stal'*, 1959, (6), 552) Facing with SV–08 steel in the form of 4–6·5 mm wire or with STO–3 rimming steel wire, the rolls being preheated to 350–400°C increases the life for a 320 mill from 12–14 days to 25–30 days.

Bonding brass to steel with a gas flame I. A. Nenaezdnikov (*Svarochnoe Proizvodstvo*, 1958, July, 35–38) Cracking has been observed in brass-faced steel and studies have been made on cast L–35 and rolled 40 steel as well as on a shipbuilding Cr–Ni–Mo steel faced with 3–6 mm brass (or 22–24 mm steel). The incidence of cracks was observed, one factor being the complexity of the shape of the specimen. Heating to 900–950° produced more cracks than heating to lower temperatures. Temperatures suitable for various specimens are recommended, the heating should be uniform, and the torch should be positioned to reduce Zn oxidations. Cast specimens should be annealed before facing.

POWDER METALLURGY

The production of iron powder J. Kubelík (*Hutn. Listy*, 1959, **13,** (12), 1129–1131) The economics of iron powder production are considered with special reference to Czechoslovak conditions. The iron/iron oxide method of atomizing liquid cast iron and reducing the product to iron powder having a low carbon content is shown to be most suitable. The iron can be pressed for making sintered machine components having satisfactory properties.

Sintering – a versatile process H. C. Renken (*Battelle Tech. Rev.*, 1959, **8,** May, 3–7) A general review of the development of the process and its underlying principles, here mainly non-ferrous.

Metal sinterings: a guide to their application in industry British Metal Sinterings Association (*Pamphlet*, [1959], pp. 32) A general account of the processes, design, properties, and uses of sintered metal powders, with tables and illustrations.

FERRITES, CERMETS, AND CARBIDES

Iron oxides as raw materials for the manufacture of magnetic ferrites R. A. Stephens (*Am. Ceram. Soc. Bull.*, 1959, March, 106–109) Synthetic iron oxides are classified into 7 types according to method of production. Particle size and shape are measured and other physical properties and chemical compositions are recorded.

Process makes better cermets at lower cost (*Steel*, 1959, **144,** Jan. 26, 84) The process of electrophoretic deposition developed by Vitro Corp. of America is described. Coatings of refractory metals or ceramics can be deposited on a metal body in graded layers. In principle, an electrostatic field is established between the workpiece and an electrode immersed in a suspension of charged particles so that the particles adhere to the workpiece. Metallic oxides and/or ceramic materials can be used; the former can then be reduced to the metal; successive layers can be added to give required properties.—D.L.C.P.

PROPERTIES AND TESTS

Conference for the co-ordination of scientific research for ferrous metallurgy in 1959 N. S. Boikov (*Stal'*, 1959, (3), 286–287) A report of a meeting in Nov. 1958 where problems for investigation during the succeeding year were propounded. These are listed in some detail.

Inspection of ball-bearing steel for non-metallic inclusions: comparison of results obtained with forged and rolled samples V. F. Iaupov (*Stal'*, 1959, (5), 461) A note on research by the Serov Combine. Sufficient uniformity was found for the number of samples examined to be greatly reduced.

Relaxation strength of spring steel as depending on structure stability V. Ya Zubov and S. V. Grachev (*Fiz. Met.*, 1958, **6,** (6), 1088–1094) An increase in the stability of the structure of steel may either increase or decrease the relaxation strength, depending on the conditions of the relaxation and on the structure of the steel. The influence of the displacing mechanism of relaxation is greater with greater structural stability. Of the two steels investigated, EI722 and EI1142, the former has the greater relaxation strength.

Study of cleavage surfaces in ferrite. Final report for Oct. 1948–Oct. 1949 E. P. Klier (*ATI* 66495; *PB* 130949, 1949, Oct., pp.35) X-ray, fractographic and metallographic studies are reported. Plastically strained metal was observed at such surfaces in coarse-grained ferrite over a wide range of testing conditions.

Investigations into the accuracy of the Erichsen cupping test V. Kokkonen and G. Nygren (*Sheet Met. Ind.*, 1959, **36,** Mar., 167–178) A report of work by the Jernkontoret research organization. Nine batches of material were tested on 10 machines. The variations found were not explained by variations in depth of cup due to surface roughness and punch radius.

Growth bends in iron whiskers G. S. Baker (*AD* 96222; *AF OSR TN* 56–413; *PB* 126930, 1956, Oct., pp.3) Whiskers grown from the vapour were shown to have the bent part at a twin or other boundary.

Vacancies and other point defects in metals and alloys (*Inst. Metals Monograph and Report Series No.* 23, 1958, pp.238) **Point defects and the mechanical properties of metals and alloys at low temperatures** A. H. Cottrell (1–39) Introduction by irradiation, quenching, defects of composition and cold work is reviewed and the hardening and embrittlement produced and the process of yielding, the hardness of the material and the mechanisms of the various processes described are reviewed (148 refs.). **The effects of lattice defects on some physical properties of metals** T. Broom and R. K. Ham (41–78) Mainly non-ferrous. Effects on stored energy, resistivity, density, X-ray lattice parameters, thermoelectric properties, heat conductivity, magnetic properties and nuclear magnetic resonance are discussed and annealing processes are considered. Discrepancies between theory and experiment are noted (141 refs.). **Point defects and diffusion in metals and alloys** W. M. Lomer (79–98) Vacancy-diffusion mechanisms are particularly considered and a distinction is drawn between homogeneous systems in which tracer methods must be used and inhomogeneous systems in which ordinary chemical diffusion occurs. Mass transport is surveyed and the relations between diffusion coefficients in dilute binary alloys are examined (54 refs.). **Point defects and mechanical properties of ionic crystals** P. L. Pratt (99–130) (106 refs.). **Point defects near the surface of a metal** E. C. Williams and P. C. S. Hayfield (131–157) A higher concentration of vacancies might be expected near a surface and the possibility of Gibbs' adsorption is also discussed. Effects of mechanical working on metal surfaces is considered in relation to point defects. Non-ferrous examples of oxidation and corrosion effects are given. **Point defects and the mechanical properties of metals and alloys at high temperatures** D. McLean (159–198) Creep is discussed in terms of the climb of dislocations (109 refs.). **General discussion** (199–294).

X-Ray measurement of the distribution of electrons in iron and copper R. J. Weiss and J. J. De Marco (*Phys. Rev. Letters*, 1959, **2,** Feb. 15, 148–149) Corrections of various kinds applied to measured values give 2·5 ± 1·5 as the no. of 3*d* electrons in Fe.

On the solid solubility of copper in low carbon steel. I. K. Yoshizuki (*Toyo Kohan*, 1953. **II, 1,** Dec., 1–27, 1954, **3,** May, 14–27) Samples containing varying amounts of copper were made in an experimental induction furnace, and were cold-rolled and annealed in nitrogen. Results of measurements of mechanical properties, electrical resistance, specific heat and X-ray diffraction patterns are reported. The metallography and relationships between time and hardness during annealing of low-carbon steels containing various amounts of copper are examined. The limit of solid solubility of copper in low-carbon steel is approximately 0·4%. Ageing phenomena of copper-bearing steels are negligible at room temp., but significant at 600°C.—K.E.J.

Transverse mechanical properties of slack-quenched and tempered wrought steel J. Vajda, P. E. Busby, C. Wells, and R. F. Mehl (*AD* 33462; *AF WADC TR* 53–515; *PB* 133172, 1954, Feb., pp.48) A method for developing reproducible structures in heavy steel section is described so that transverse mechanical properties could be related to hardenability. The separate and combined effects of B, C, Si and rare earths were studied and also the effects of mass or mechanical properties and degree of slack quenching on impact test transition temp. Cooling rate data associating cooling rates with structure are given.

Effect of austempering, martempering, and interrupted quenching on transverse properties and distortion and strain-ageing on yield-tensile ratio J. Vajda, J. J. Hauser, P. E. Busby, *et al.* (*AF WADC TR* 54–588; *PB* 133197, 1954, Dec., pp.43) Cylindrical specimens of AISI 4340 up to 2 in. dia. and 4350 up to 3 in. or more can be treated in these ways to give the same properties as those obtained by the conventional oil quench and tempering of small specimens. Distortion in martempering is shown to be at a minimum at a temperature depending on size and composition.

Make strains visible with photo stress analysis F. Zandman (*Prod. Eng.*, 1959, **30,** Mar. 2, 43–46) A method is described for observing and reading strains in parts under load, based on the use of a doubly refracting plastic applied as a coating. Practical applications are discussed including a torquemeter.

Adhesive speeds bonding of strain gauges (*Steel*, 1959, **144,** Feb. 23, 96) Eastman 910 adhesive is rapid curing at normal temperatures and gives a strong bond on almost any surface. It is recommended for attaching strain gauges which can be read 5 min after application.—A.G.

Interpretation of the mechanism of the strain gauge and of its most important properties demonstrated by a model C. Rohrbach and N. Czaika (*Materialprüfung*, 1959, **1,** Apr. 20, 121–131) A model in which only a shearing

stress is present is calculated giving two expressions for gauge and wire properties and creep. These are evaluated for the PR 9210 gauge, and comparison with observed values justifies the simplifications introduced.

Tension and impact properties of steel heat treated to 160 000–190 000 psi yield strength at temperatures between −40°F (impact) and 800°F (tension) N. J. Manzari and G. Sachs (*WAL R* 310/210; *MET* 348–572 *F*; *PB* 132051, 1956, Aug., pp.118) The stability of tensile and impact properties of three low-alloy steels with 0·25–0·35%C was tested by cyclic tempering between 400° and 900°F up to 1 000 times for 5 min each, and changes of tensile strength were measured up to 800°F and impact strength between −320° and +560°F.

Grain boundary migration and dimensional change of low carbon steel M. Okada and T. Watanabe (*J. Phys. Soc. Japan*, 1959, **14,** Jan., 107–108) Steel rods with 0·2%C were extended or compressed 14%, annealed for 30 min and measured. Rods annealed below 100° contracted, above 100° length increased and diameter decreased for extended specimens, and the reverse for compressed specimens, the volume remaining nearly constant. These effects are referred to grain boundary migration.

Static load-bearing capacity of components under elastic-plastic strain (R. M. Schneiderovich (*Vestnik Mashin*, 1959, (1), 14–24) A theoretical study of the safety factor for components subjected to static strain during normal conditions of service.

A simple bend test to measure uniformity of ductility in sheet metal S. V. Arnold (*PB* 131947, *WAL* 401/283, pp.6) Apparatus is shown in which bending is by means of a die system and the angle is read off directly. It is claimed that the test is sensitive to incipient rupture.

An instrument for the examination of changes on bent test-pieces Z. B. Sólyom (*Acta Techn.*, 1959, **22,** (1–2), 3–11) An apparatus is described by which the compression and extension of a bent test piece and the location of the neutral fibre can be determined by recording the mutual rotary displacements of two sectional lines in a hyperbolic-spiral coordinate systems. Results are described on non-metallic materials.

Hot workability of carbon steels T. Koinumaru (*Tetsu to Hagane*, 1958, **44,** Sept., 1079–1081) For 9 steel specimens, compositions, gas analyses, inclusions and austenitic grain size are given, and the effects of temp. on torsional and shearing behaviour are shown.—K.E.J.

On the hot-workability of round steel billets I. Hot-torsion test on the segregation zones of low-carbon killed steel billets J. Kubodera (*Tetsu to Hagane*, 1958, **44,** Sept., 1053–1055) The hot-workability is shown to fall with increase of distance up the ingot, in a series of regular curves for different temp.—K.E.J.

The resistance of rail car bodies of welded light steel construction M. Hug (**Glaserz Annalen*, 1957, **81,** Mar., 83–87) Tests to permanent deformation are reported.

The examination and testing of metallic materials by physical methods H. Thompson (*Inst. Auto. Assessors J.*, 1959, **10,** Apr., 29–47) An illustrated account of impact, creep, fatigue, magnetic, ultrasonic, and X-ray testing.

Effects of aluminium additions and variations in finishing temperature on properties of hot-rolled experimental open-hearth steels R. H. Frazier, F. W. Boulger, and C. H. Lorig (*Ship Structure Committee*, SSC–90, 1955, July 15, pp.54) Commercial and experimental steels rolled to ¾ in. plate were examined for suitability for ship plate. Al up to 0·04% had no appreciable effect on Charpy and tear test values. Variations in final hot pass temperature between 1650–2060°F influenced transition temp., each increase of 100°F raising it 6°F for Charpy keyhole and 8°F for tear. Ferritic grain size was unchanged up to 0·04%Al. Over 0·01% acid-soluble Al had higher grain-coarsening temp. so that normalizing from 1650°F gave finer grains than did semi-killed steels. It also lowered Charpy transition temp.

Behaviour of pure iron under dynamic tensile loading M. Omori (*Tetsu to Hagane*, 1958, **44,** Sept., 1109–1111).—K.E.J.

The shape of the temperature curve of notch toughness and the fracture face in the transition from high to low values G. E. Tummers, A. Schepers, and F. R. Licht (*Stahl Eisen*, 1959, **79,** Feb. 19, 215–216) Two letters. The first disputes the significance of the findings of the latter authors published in *ibid.*, 1958, **78,** 227, and they reply.—T.G.

Effect of various alloying elements on notch-sensitivity of 2% Mn high strength steel T. Saito (*Tetsu to Hagane*, 1958, **44,** Sept., 1111–1112) The elements studied are C, Si, Cr, Mo, W, Ti, V, (Ti + B), and Cu.—K.E.J.

Investigation of the influence of deoxidation and chemical composition of notched-bar properties of ship plate steels F. W. Boulger, R. H. Frazier, and C. H. Lorig (*Ship Structure Committee, Serial No. SSC–91*, 1955, July 15, pp.58) Killed and semi-killed steels were used. Increase in Mn decreased transition temp. and increased resistance to brittle fracture. Increase of C, P or N raised this temp. and so brittle-susceptibility. N_2 is not necessarily detrimental in Al-killed steels. S up to 0·06% and Ti + Zr in the usual amounts had no effect; Ti above 0·04% increases transition temp. and Zr above 0·04% might be beneficial. Raising V from 0·1 to 0·2% raised transition temp. 80°F. Increasing deoxidation with Si or Al lowers transition temp. but only small amounts are present in semi-killed steel, they had no significant effect on grain size. Al up to 0·2% in killed steels lowers transition temp. and this in the presence of 0·01, 0·05 or 0·1%Si. Si usually lowers transition temp. up to 0·15%, above this the effect depends on the Mn and Al contents. Various recommendations are made.

Testing structural steels insensitive to brittle fracture with bursting experiments H. Hauttmann (*Schweisstechn.*, 1959, **13,** Feb., 13–19) The results are described of bursting tests on welded tubes made from the Aldur series of steels, with comparative results on two other types. Various tube dimensions, weld types and heat treatments were used.

Some factors which affect the notch impact properties of carbon steels: the influence of aluminium and nitrogen on the strain ageing of steels H. Gondo (**Tetsu to Hagane*, 1957, **43,** Sept., 894–897) Steels melted in a h.f. furnace with or without addition of 0·1%Al and also oxygen converter and basic OH steels forged or rolled into plates 12–30 mm thick were subjected to tensile strain of 0–15% at ordinary temp. and the Charpy V-notch impact values were compared at temp. from −60°C to +100°C at 20° intervals. Attempts were made to isolate the effects of the Al and N contents. Graphs and tables of the results are given. The Tr 15 concept from William's formula was used and dislocation theory is also called upon to interpret the results. The converter steels were not found inferior to the basic OH steels and they were not considered separately.

Normalization procedures for NRL drop-weight test P. P. Puzak and A. J. Babecki (*NRL Report* 5220, 1958, Nov., pp.20) Test data for 90 steels are given and surface strain determination is explained in terms of crack-opening after welding at ~100°F above NDT temp. Test conditions are established and their effectiveness is discussed.

Structural changes in high-carbon steel attacked by shaped charges A. Soundraraj and Sampooran Singh (*J. Sci. Ind. Res.*, 1959, **18B,** Feb., 86–87) The structures produced by shaped charges with a copper liner are illustrated and described. The steel had 0·71%C and a ferritic grain boundary network surrounding pearlite.

Fracturing under explosive loading J. S. Rinehart (*Chem. Eng. Prog.*, 1959, **55,** Feb., 59–64) Fracture patterns are investigated and the various factors involved in breakage by impulsive loading are discussed.

Fundamental study of weld joint behaviour: explosion-bulge test performance of HY-80 weldments A. J. Babecki and P. P. Puzak (*Rept. NRL Progress*, 1959, *PB* 151334–125, Jan., 33–34) A method of welding satisfactory for this steel has been developed and various tests are described. **Explosion-bulge test performance of 1-inch thick experimental low-carbon ST5 weldments** (34) Tests on submerged arc welded specimens in comparison with manual-arc are noted.

Study of the technological properties of, and of the residual stresses in, drawn free-cutting rod steel A. Schepers and A. Peiter (*Stahl Eisen*, 1959, **79,** Mar. 19, 337–349) Cold-working characteristics, susceptibility to cracking and the distribution of longitudinal residual stresses were studied on two free-cutting steels – one of them leaded – reduced by drawing to various extents. Coagulation of Pb in the rim of the leaded steel bars leads to cracking, the cracks are small and no large longitudinal crack was found. Means of reducing the crack susceptibility of the leaded steel are discussed. Reduction during drawing has to be carried out in two steps in order to reduce crack susceptibility (54 refs.).—T.G.

Influence of surface-active media on the surface work-hardening of metals G. I. Epifanov, N. J. Glagolev, and P. A. Rebinder (*Doklady AN*, 1958, **123,** (4), 663–666) Experiments were performed on pure iron, surface-hardened in air and in various active media. The influence of the number of rolling passes on the microhardness was studied, as well as the force of friction, structure of the surface, specific work and temperature. The results of study of iron used in the presence of a solution of stearic acid in decalin are shown in three graphs and the results are discussed.—S.I.T.

Effect of deformation prior to transformation on the mechanical properties of 4340 steel E. B. Kula and J. M. Dhosi (*Trans. ASM preprint No.* 129, 1958, **52,** pp.35) A method of hardening by deforming in the austenitic state and quenching to form martensite before recrystallization occurs was examined. The steel was rolled at 1000° and 1550°F to a 72% reduction, followed by tempering, and improvement in tensile and impact properties was noted. Mechanisms are discussed.

A theory of elastic, plastic, and creep deformations of an initially isotropic material showing anisotropic strain-hardening, creep recovery, and secondary creep J. F. Besseling (*J. Appl. Mech.*, 1958, **25,** Dec., 529–536) Stress/strain relations are given for an initially isotropic material, which is macroscopically homogeneous, but inhomogeneous on a microscopic scale. An element of volume is considered to be composed of various portions which can be represented by subelements showing secondary creep and isotropic work-hardening in plastic deformation. Only quasi-static deformation under isothermal conditions is considered. The theory is restricted to small total strain.—T.G.

Effect of sulphur in the furnace atmosphere on the hot-workability of steel III. Experiments on sulphur in the heating atmosphere of the heating furnace T. Morishima (*Tetsu to Hagane*, 1958, **44,** Sept., 998–1000).—K.E.J.

Fatigue since Wohler A. J. Kennedy (*Engineering*, 1958, **186,** Dec. 12, 781–782) An outline of the development of research methods and theory, with a criticism of the SN test.

A high-temperature, vacuum, and controlled-environment fatigue tester G. J. Danek jun. and M. R. Achter (*ASTM Bull.*, 1958, Dec., 48–52) A fatigue testing machine is described for reverse fatigue bending *in vacuo* (down to 3×10^{-5} mm Hg) at temperatures up to 1500°F. Large strain amplitudes at low frequencies are used to produce failures at approx. 10^5 cycles. The transmission of motion through the vacuum seal was solved by magnetic coupling. The tests are automatically stopped when a crack has developed. Fatigue data are presented for type 316 stainless steel.

A note on the effect of pressurization on the fatigue life of metals L. W. Hu (*ASTM Bull.*, 1958, Dec., 63–65) The reasons why the fatigue strength of metals may be affected after being exposed to a hydrostatic pressure of high intensity are briefly discussed and preliminary results of tests on carbon steel C1045 and Al alloys are reported. There is an indication that for the steel the fatigue life is reduced by pressurization.—T.G.

High-temperature fatigue testing – with application to uranium J. R. Bohn and G. Murphy

(*ASTM Bull.*, 1958, Dec., 57–60) To overcome difficulties in fatigue testing at elevated temperatures when the material is subject to oxidation, two methods of protection, plating and encapsulation, are discussed. Plating is useful in the range from 200—400°C, above this temperature encasing the specimen is recommended. Tests on U at temperatures up to 600°C indicate that the encasement method is superior to other methods of protection.

Improvement of the fatigue strength of notched specimens by artificially induced residual stresses T. R. Gurney (*Nature*, 1959, **183,** Mar. 28, 883–884) A letter. Tests by the British Welding Research Association have confirmed the effect, the stresses were produced by compression of adjacent areas.

A toric bending specimen for investigation of geometrical factors in fatigue J. A. Bennet and J. G. Weinberg (*ASTM Bull.*, 1958, Dec., 53–56) A plate bending-fatigue specimen having an anticlastic surface in the reduced section is described. This was developed to study the commonly observed fact that fatigue cracks start at the corners of the cross-section of conventional specimens, i.e. that the resistance to fatigue crack initiation is lower at a corner than on the flat surface of the specimen. Preliminary results with specimens having an anticlastic surface indicate that the presence of a corner does not reduce the resistance to fatigue crack initiation.—T.G.

Research on ferrous materials fatigue H. N. Cummings, F. B. Stulen, and W. C. Schulte (*WADC Tech. Rep.* 58-43; *ASTIA Document No.* 155772; *PB* 151243-250, 1958, Aug., pp.104) Effects of fatigue stressing on steel rotating-beam specimens were studied. Rate of crack propagation, effects of surface hardening by mechanical treatment, plating, nitriding and carburizing, and the transverse properties of SAE 4340 steel were examined. Limitations of the Prot method are disclosed. Rolled and forged SAE 4340 steel showed some decrease in transverse as compared with longitudinal strength.

A machine for evaluation of high-temperature alloys under combined static and dynamic stresses P. E. Hawkes and C. H. Ek (*ASTM Bull.*, 1959, Jan., 46–51) A resonance-type machine is described. It simulates turbine bucket and combustion chamber conditions over the range 1000–1800°F. Tests on two alloys are given as examples.

Fatigue fracture. Commission XIII of the Inst. Internat de la Soudure (*Rev. Soudure*, 1958, **14,** (4), 222–225) An account of an investigation carried out by the committee into the cause of the fracture of a flanged pipe forming part of an air compressor.

Fatigue strength of steel test pieces, flame cut and repaired by welding A. Matting, H. Wolf, and H.-D. Steffens (*Schweissen Schneiden*, 1959, **11,** Jan., 8–16) Conditions are examined under which damage and defects caused in flame cutting, particularly of steel sheet, can be made good by welding, without detriment to the fatigue strength. Design of the test piece and a suitable welding technique are discussed (20 refs.).

On the relation between the thickness of decarburizing layers and the fatigue strength of carbon steel S. Tsujimoto (*Tetsu to Hagane*, 1958, **44,** Sept., 1075–1077).—K.E.J.

High-temperature fatigue strength of austenitic stainless steels K. Ebato (*Tetsu to Hagane*, 1958, **44,** Sept., 1134–1136).—K.E.J.

Microfractographic investigation of the surfaces of fatigue fractures. Example of application J. Plateau, C. Crussard, J. Faguet, G. Henry, M. Weisz, G. Sertour, and R. Esquerre (*Rev. Mét.*, 1958, **55,** July, 679–695) Surfaces of fatigue fracture in various steels and alloys have been examined by electron micrography using direct carbon replicas (microfractography). These surfaces frequently show more or less marked striations which appear to correspond to successive positions of the fracture front and are also related to the cross slip. The advantages of the technique over examination by the naked eye or with a binocular microscope is explained with an example.—B.G.B.

A micro tension-compression machine for tests at 5000 cycles per second G. Vidal, F. Girard, and P. Lanusse (*Rev. Mét.*, 1958, **55,** July, 613–619) The machine described is suitable for steel specimens of 4 mm² cross-section and the maximum load amplitude is ± 250 kg. Some results obtained with an Al alloy at different frequencies are discussed.—B.G.B.

Fatigue micromachine for tension compression tests at 92000 cycles per second F. Girard and G. Vidal (*Rev. Mét.*, 1959, **56,** Jan., 25–39) A description is given of a micro-fatigue testing machine consisting of a piezo-electric exciter with mechanical amplifier which sets up alternating stresses in the specimen. The machine is only suitable for alloys with low damping. (Non-ferrous examples are given.)

Determination using a Prot machine of small differences in the fatigue limit between different parts of fabricated components in carbon steel A. Ferro and V. P. Rossetti (*Rev. Mét.*, 1958, **55,** July, 650–655) Forged parts have been examined to find possible differences in fatigue limits in various regions, in particular in the vicinity of joints where there has been heavy deformation. The results have shown that in general there are no significant differences between the fatigue limits of specimens taken from different parts of the forging. A discussion of the Prot technique is added.—B.G.B.

Relation between the critical alternating propagation stress and crack length for mild steel N. E. Frost (*Chartered Mech. Eng.*, 1959, **6,** May, 201–203) Curves from rotating bend fatigue and reversed direct stress tests are plotted and the relationships evaluated.

Effect of surface defects in crankshafts on their fatigue strength A. T. Wuppermann, M. Pfender and E. Medick (*Verein Deutscher Eisenhuttenleute, Special Publication*, **1958,** 48 pp.) Sixteen different crankshafts, some new, some after considerable use, some with definite defects starting at the surface, some without any visible defect were fatigue-tested. These tests were supplemented by mechanical and metallographic examinations. In spite of very much higher loading than normal and large extension of the fatigue test not one crankshaft failed at a defect for which it was rejected. The results of the tests and other examinations are reported in detail.

Contribution to the physical examination of fatigue damage M. Weisz (*Rev. Mét.*, 1959, **56,** Jan., 83–103) A review of experimental results, with the object of defining or determining fatigue damage by means of physical measurements. It is suggested that this can be done (a) by determining the effect of damage at the stress value corresponding to 50% failure before 5×10^6 reversals, (b) investigating the low-temperature mechanical properties of the metal when subjected to various degrees of damage.

Contribution to the study of the statistical aspect of fatigue F. Bastenaire and M. Weisz (*Rev. Mét.*, 1958, **55,** Aug., 785–796) The first part of the paper deals with the influence of tensile properties on the relative dispersion S/C of the results of fatigue tests. The second part is a statistical study of under-loading, made on a $35CD_4$ steel, and mild and high-strength steels.

Comments on cumulative fatigue damage W. Weibull (*Rev. Mét.*, 1958, **55,** Aug., 778–784) Reasons for the breakdown in some cases of the linear hypothesis of fatigue damage are discussed, and it is shown to be due to the fact that the assumption that the endurance limit remains constant during the fatigue process is incorrect. Some examples are given of the determination of this limit.

Investigating the effect of frequency on alternation of load on the resistance of Armco iron V. I. Shabalin (*Zavods. Lab.*, 1958, (9), 1110–1112) Experimental findings show that an increase in frequency from 20 to 3000 cycles per min results only in a small increase in the endurance strength of Armco iron (from 22 to 23 kg/mm²) but the service life of the specimens under the alternating cyclic load is influenced to a much larger degree; at a rate of 20 cycles per min it corresponded to 600 000 cycles and at a frequency of 3000 cycles, to 1 100 000 cycles.—L. H.

Some data regarding the vibration resistance of St.3 kp steel A. A. Bat' (*Avtom. Svarka*, 1958, (8), 63–68) Investigations are reported with equal alternating loads on girders of tempered St.3 kp steel. These show that fatigue cracks can form during repeated compressions with alternating small stress concentrations. It was not, however, possible clearly to establish the influence of any preceding compressions on the subsequent repeated alternating tensile stresses, and this problem requires further investigation.—L. H.

Method of fatigue testing under variable loads and the nature of the fatigued surface D. N. Reshetov and S. A. Shuvalov (*Vestnik Mashin.*, 1958, (9), 3–7) A theoretical study based on the assumption that resistance to fatigue under changing loads depends both on the magnitude of the maximum and minimum loads and on the pattern of their variation. The numerical value of the tests undertaken is expressed by the number of cycles to the moment of failure. The nature of the fatigued surface is characterized by fatigue curves constructed for constant and changing conditions of the experiments for different sections of the surface taken in various directions.—L. H.

Fatigue-service life prediction based on tests at constant stress levels C. R. Smith (*Proc. Soc. Expt. Stress Anal.*, 1958, **16,** 9–16) Work on clad Al is reported, Five stress levels were used, the specimens were statically loaded once to the highest load used before testing. Much lower values than usual were obtained for $\Sigma n/N$.

Theory of the change of metals during fatigue. Variation of the spatial distribution of the stability of obstacles to plastic slip W. Barrois (*Rev. Mét.*, 1958, **55,** Aug., 761–777) A theory is developed based on the hypothesis that fatigue fracture is the result of a process in which internal reactions to external forces are distributed amongst domains decreasing in size and number during the application of mechanical effort. This effort increases the differentiation between plastic rigidity and spatial distribution of the stability of the metastable atomic or molecular configurations, and some domains are restored to their original or to a new condition, while the disorder of others is increased. Some ferrous examples are cited (56 references).

The effects of mean stress and of preloading on the fatigue life of a high tensile structural steel (Ducol W25). Part I F. H. Hooke (*Ministry of Supply Tech. Inf. and Library Services, S and T Memo. No.* 20/58, 1958, Oct., pp.21+ Tables and Figs.) Notched Al specimens showed improved fatigue life after single applications of high tensile load so tests on notched steel were made on similar lines. Tensile loads up to 32 t/in² had no significant effect and above this fatigue life was reduced.

The influence of crystalline orientation on bending fatigue strength and on the formation of slip bands in single crystals of alpha-iron M. Hempel and E. Hillnhagen (*Rev. Mét.*, 1958, **55,** Aug., 749–769) Wöhler curves have been determined on single crystals and polycrystalline specimens of Armco iron, the relations between bending fatigue strength and the corresponding static strength values examined, and the influence of crystal orientation on the Wöhler curves assessed. The influence of stressing conditions on the formation of slip bands on the surface of cyclically stressed specimens, and the relation between the position of fatigue cracks and the direction of grain boundaries were investigated metallographically (36 references).

Contact fatigue of uncemented medium carbon steels hardened by high-frequency current T. N. Nazarova (*Metallov. Obra. Met.*, 1958, (11), 57–59) For steels 45 and 45Kh, the conventional limit of contact fatigue is reached with a skin depth of 3 mm and over and is 23-200 kg/cm² for 45Kh steel and 22-000 kg/cm² for 45 steel. For steels hardened with high-frequency currents to a depth of 3 mm and over, the limit of contact fatigue is very near that of cemented steels.

The relation between the distance of an inclusion from the surface and the influence of this inclusion on fatigue fracture H. de Leiris and A. Frappier (*Rev. Mét.*, 1959, **56,** Jan., 11–24) To examine the reason for the fact that fatigue cracks appear to be initiated from subsurface in preference to surface cracks, a

photoelastic investigation was made into the effect of distance from the surface on stress distribution round the hole. It was found at a certain region that stresses were higher than those due to a circular notch cut at the surface

Improvement in the [fatigue] strength of [machine] parts by hardening and pre-stressing the joints J. Pomey, J. P. Georges, and A. Royez (*Rev. Mét.*, 1959, **56,** Jan., 1–10) It is pointed out that the service life of parts subjected to alternating stresses is reduced by notch effects set up by changes of section in the component. Procedures to be adopted to improve life by reducing these notch effects are described, and illustrated by some examples.

Fatigue damage of plain carbon steels – effect of reheating T. Yokorori (*ASTM Bull.*, 1958, **234,** Dec., 66–67) The fatigue damage according to French's definition cannot be repaired by subsequent annealing. It can, however, be repaired by understressing, but this appears to be lost by subsequent annealing for stress relief.—T.G.

Effect of shot peening prior to electroplating on the fatigue properties of an alloy steel N. B. Brown (*Dept. Mines Techn. Survey, Ottawa, Res. Rep.* R23, 1958, Sept. 18, pp.12) A SAE3140 steel was used and tested as-machined, shot peened and electroplated on machined and on peened surfaces with Cr, Ni, and Cd. The peened specimens had better fatigue properties than those plated without peening.

The effect of surface treatment and cadmium electrodeposition on the fatigue properties of some high tensile steels P. R. Wedden and W. E. Cooper (*Ministry of Supply* S & T Memo. 19/58, 1958, Oct., pp.23) Fatigue tests on two types of steel after surface preparation and Cd plating were carried out. Grit-blasted Cd-plated steel baked 30 min at 175°C showed no significant change in fatigue strength at 80 and 110 t/in². Although relatively high residual compressive stress remained in the machine surface of unnotched specimens before pickling, little effect on fatigue properties were produced by plating and baking. In notched specimens, fatigue strength was reduced, the higher strength material more severely, this was not removed by baking at 175°C. Alkaline derusting solution, instead of pickling showed little improvement, but grit blasting before pickling inhibited and may have eliminated the reduction in fatigue strength.

Effect of shot-peening on fatigue strength of metals. II. Effect on decarburized steels S. Takeuchi and T. Homma (*Sci. Rep. Res. Inst. Tôhoku Univ.*, 1959, **11A,** Feb., 48–55) A Si–Mn spring steel was examined and the effect of a decarburized surface layer and the effect of shot peening were observed. A layer even 0·05 mm thick halved the fatigue strength, thicker layers had little more effect. Shot-peening of these specimens increased the fatigue strength 40–50% at 10^7 cycles.

Effects of environment on high-temperature properties of metals G. J. Danek jun. and M. R. Achter (*Rept. NRL Progress* 1959, *PB* 151334–125, Jan., 30) Type 316 stainless was examined at 1500°F. Fatigue tests in air and vacuum seemed to show a reversal of the effect observed in creep rupture with decreasing strain rate.

An investigation into the creep properties of two cast irons C. Wheatley and J. A. Pope (*Trans. NE Coast Inst. Eng. Ship.*, 1959, Preprint, 331–354) A rapid test was developed for the examination of Diesel pistons. Miniature compressive creep and test relaxation studies can be made and a quick-sorting test was evolved and tried on medium flake graphite irons.

The role of subgrains in high temperature creep L. A. Shepard and J. E. Dorn (*WADC Tech. Rep.* 58–63; *ASTIA Document No.* 155565; *PB* 151208–100, 1958, May, pp.33) The origin of sub-grains is discussed and the deformation modes which produce the sub-structures observed. The effect of creep variables on sub-grains is described and an attempt is made to relate sub-grain structure to creep, recovery, and grain boundary shear. It is concluded that its relative contribution to creep resistance is small.

Creep of hard pre-stressed steels in the range of temperatures termed 'normal'. Influence of variations in stress and of temperature R. de Strycker (*Rev. Mét.*, 1959, **56,** Jan., 49–54) For short-time tests the influence on creep of stress variations is not highly sensitive to the length of the period. Creep of hard steels varies greatly with temperature.

Studies on 12% chromium heat-resisting steels. X. Effect of heat treatment on creep rupture strength T. Fujita (*Tetsu to Hagane*, 1958, **44,** Sept., 1139–1141). **XI. Long period creep rupture properties and tempering hardness** T. Fujita (*Tetsu to Hagane*, 1958, **44,** Sept., 1141–1143).—K.E.J.

On the function of nitrogen as an alloying element in heat-resisting materials III. Hot-cold work and bending creep properties of 16–15–6 type alloys R. Tanaka (*Tetsu to Hagane*, 1958, **44,** Sept., 1147–1149).—K.E.J.

Effect of a ceramic coating on the creep behaviour of some high-temperature alloys J. R. Cuthill, J. C. Richmond, and N. J. Tighe (*Am. Ceram. Soc. Bull.*, 1959, **38,** Jan., 4–12) Tests on 310 stainless steel (and 80Ni–20Cr alloy) at 1800°, 1900°, and 1975°F and also constant load tests at 1900° and 1975°C were carried out for 100 h with coatings of NBS ceramic coating N–143. Creep was generally decreased but some combinations of temp. and stress disclosed a detrimental effect.

The creep and rupture properties of 2¼% chromium–1% molybdenum quality steel J. D. Murray, J. S. Blair, G. G. Foster, H. W. Kirkby, and J. Blackhurst (*JISI*, 1959, **193,** Dec., 354–359) [This issue].

The influence of annealing twins on intergranular creep cracking C. W. Weaver (*J. Inst. Met.*, 1958, **87,** Dec., 126–127) The progress of an intergranular creep crack along a transverse boundary may be delayed by the vertical intergranular boundary of an annealing twin. Experimental evidence is produced which suggests that the crack may also be stopped by deformation.—T.G.

A review of intergranular fracture processes in creep P. W. Davies and J. P. Dennison (*J. Inst. Met.*, 1958, **87,** Dec., 119–125) The qualitative and quantitative aspects of the theories relating to internal fissuring during creep at elevated temperatures are reviewed, and it is shown that different processes become operative according to the prevailing conditions of stress and temperature (37 refs.).—T.G.

Microstructural changes in a 42%Ni, 30%Cr, 26%Fe alloy during creep-rupture testing R. J. Raudebaugh and E. P. Sadowski (*Trans. Met. Soc. AIME*, 1959, **215,** Feb., 23–29) The microstructural characteristics of this alloy, made under industrial conditions, were correlated with its behaviour in creep and rupture test at 1400°, 1600° and 1800°F. N_2 determinations were made after testing, adjacent to the fracture or from the mid-gauge length where tests were discontinued before fracture. Nitrogen pick-up observed at 1600° and 1800°F was associated with fissuring of specimens prior to fracture.

Relief of thermal stresses through creep H. Poritsky and F. A. Fend (*J. Appl. Mech.*, 1958, **25,** Dec., 589–597) Equations are derived for analysing the effects of creep on stress distribution. The equations are applied to the axially symmetric problem of relief of thermal stresses in an infinitely long cylinder which is quickly heated to a parabolic temperature and maintained at that temperature. The methods developed are illustrative of a procedure which may be followed for other stress-creep problems.—T.G.

Hardness testing G. H. Jackson (*Met. Treatment*, 1959, **26,** Jan., 28–30, 32) A NADFS Spring lecture.

On ball indentation II: Strain figures developed in and on the ball-indented specimen S. Yazawa, K. Sato, M. Unno, and G. Yaguchi (*J. Mech. Lab.*, 1959, **13,** Jan., 24–29) A⅜-in. ball was used and surface and cross-sectional strain figures were observed in a 0·19%C specimen. These are described, and Meyer's law was tested and found not to be suitable for determining the limit of specimen height.

Investigation of the physical factors which determine the hardening of alloyed iron V. M. Golubkov, V. A. Il'ina, V. K. Kritskaya, G. V. Kurdyumov, and M. D. Perkas (*Fiz. Met. Metallov.*, 1957, **5,** (3), 465–483) The physical factors determining the hardening of α-iron alloyed with a number of elements were investigated on specimens cut from strip; the hardening considered was due entirely to changes in the fine structure of the α-solid solution without alterations in chemical composition. X-ray analysis and mechanical tests were used.

Research on Si–Mn–Cr spring steel I. Hardenability and mechanical properties of Si–Mn–Cr spring steel T. Miyagawa (*Tetsu to Hagane*, 1958, **44,** Sept., 1095–1097).—K.E.J.

The hardenability of lamellar-and spheroidal-graphite cast iron as a function of composition and structure H. Schiffers, D. Ammann, E. Brugger, and R. Dicke (*Forschungs. Wirts. Nordrhein-Westfalen, No.* 557, 1958, pp.29) Samples of lamellar-graphite cast iron of initially pearlitic structure showed good hardenability. Hardenability depends on degree of saturation, amount of combined carbon and quantity and distribution of the graphite. Mo greatly promoted the depth of the hardened zone. Spheroidal-graphite cast iron showed the expected good hardenability, particularly an iron that contained V and Ti. The holes in the surface of hardened cast iron are not due to burning of the graphite but more likely to breaking loose of martensite grains.—T.G.

The effect of oxygen on the toughness and ageing of steels J. Čabelka (*Zvár. Sbornik*, 1958, **7,** (4), 401–420) [In Slovak]. The solubility of oxygen in various phases present in ferritic and austenitic steels is considered on the basis of data given in the literature, as well as those obtained by the author. The existence of internal stresses due to the precipitation of oxides is explained, and shown to affect the toughness and ageing characteristics, as well as the intercrystalline strength. Tests were carried out on ferritic-pearlitic, as well as on austenitic steels. It is considered incorrect to use heat-resisting steels with retained ferrite. The formation and decomposition of sigma-phase is explained. In stainless steels, oxygen is also undesirable, as it may lead to intercrystalline corrosion.

Influence of direct and alternating current flow on the quench and strain ageing of soft iron F. Erdmann-Jesnitzer, D. Mrowka, and K. Ouvrier (*Arch. Eisenh.*, 1959, **30,** Jan., 31–33) An investigation is reported of the change with time of the electrical resistance of quenched and 75% cold-strained Armco iron wire at 80·6°C and 60°C respectively, with d.c. and a.c. currents.

On the function of nitrogen as an alloying element in heat-resisting materials. II. Ageing of 16–15–6 type alloys R. Tanaka (*Tetsu to Hagane*, 1958, **44,** Sept., 1145–1147).—K.E.J.

Brittle fracture (*Auto. Eng.*, 1959, **49,** Jan., 8–9) A brief illustrated review.

Properties of iron alloys J. E. Srawley and C. D. Beachem (*Rept. NRL Progress*, 1959, *PB* 151334–125, Jan., 27) Hardenable 12%Cr steels were examined for net fracture stress values which were related to the change from transverse brittle to oblique shear, and crack propagation tests were made.

Contribution to the discussion on the problem of brittle fracture K. Ruhl and H. M. Schadt (*Schweiz. Arch. Wiss. Techn.*, 1958, **24,** Nov., 379–381) (*cf. ibid.*, 1958, **24,** Apr., 134) This is a continuation of the correspondence arising from the article mentioned.

Cracking and fracture of steel charged with hydrogen P. Bastien (*Materialprüf.*, 1959, **1,** Jan. 20, 3–12) After discussing the essential characteristics of hydrogen embrittlement a mechanism for this effect is proposed. The movement of dislocations is considered to cause local super-saturation of H_2 in the stacking dislocations.—A.G.

Brittle fracture in welded ships: An empirical approach from recent experience J. Hodgson and G. M. Boyd (*Trans. Inst. Naval Arch.*, 1958, **100,** July, 141–165, discussion 165–180) Results of investigations of failures are given and a comparison of welded with riveted ships is made. The factors influencing brittle fracture are discussed and an improved minimum standard for notch-toughness is suggested. The formulation of steel specifications is considered and tests and acceptance criteria are

compared. Tests on the steels available and on those involved in fractures in service are reported, leading to empirical acceptance standards.

Present position of the problem of brittle fracture G. M. Boyd (*Rev. Soud.*, 1958, **14,** (4), 175–187) A review of the present state of knowledge of brittle fracture, including a general outline of the effects of welding.

Preliminary studies of brittle fracture propagation in structural steel W. J. Hall, W. G. Godden, and O. A. Fettahlioglu (*Ship Structure Committee, SSC*–111, 1958, May 15, pp.86) Tests on crack speed in wide steel plates and strain distribution in mild steel during crack propagation are reported. An insert plate was welded to full plates in a testing machine after trial of several methods. The plate is cooled in solid CO_2, loaded, and a fracture initiated by impact on a wedge which is driven into a notch. A programme on 2-ft wide plates was then carried through. Crack speeds of 1150–5900 ft/sec were recorded with peak elastic strains as high as 0·0025 in./in. near fractures with negligible permanent set. Strain pulse magnitude decreased and time increased as the distance from the fracture path and a vertically oriented strain gauge increased.

On the problem of hydrogen embrittlement of iron A. Siede and W. Rostoker (*Trans. Met. Soc. AIME.*, 1958, **212,** Dec., 852–855) H_2-charged Fe has strain-ageing kinetics which are undistinguishable from those of uncharged Fe. H_2 displaces C and N_2 from dislocation centers and H_2 embrittlement derives from the stabilization of transient and thermally generated crack nuclei.—T. G.

The relationship of the tendency of steel to reversible temper-brittleness to the temperature of repeated austenitisation B. Rotenshtein and N. Dregan (*Rev. Mét. (Bucarest)*, 1958, **3,** (3), Feb., 5–31) [InRussian].

The use of low-alloy steel in welded structures T. M. Noren (*Svetsen*, 1959, **18,** (2), 33–42) The occurrence of hot cracking, temper-brittleness, ageing susceptibility, and shrinkage cracking in low-alloy high strength steels (u.t.s. 60–80 kg/mm²), especially during welding, is examined and optimum welding and heat-treatment conditions are worked out.

On the abrasion resistance of high manganese steel Y. Kido (*Tetsu to Hagane*, 1958, **44,** Sept., 1123–1126) The wear of high-Mn, Cr-Mn, low-Mn and carbon steel, white and grey iron, SK-7, SK-4, and SS41 are tested by abrasion with sand, cement clinker and coal in a ball mill. Wear results are related to hardness.—K. E. J.

Wear of carbon steel weld metal. II. The effect of heat treatment upon the structurally changed layers and the wear volume S. Ito, K. Honda, and K. Ishiyama (*J. Mech. Lab.*, 1959, **13,** Jan., 12–17) A study of the structural change produced by dry friction in the surface layers is reported. Taper sectioning was used and the same forms were observed in both quenched and tempered specimens. Wear volume was scarcely affected. **III. The relation between rubbing conditions and the structurally changed layers of worn surfaces** S. Ito and K. Ishiyama (18–23) Sliding distance, rate and load caused similar changes in the surface layers and these were due mainly to the surface temp. produced. These layers are shown to be wear-resistant.

Phenomena of wear on tools for chip-forming machining J. L. Remmerswaal (*Metallbewerking*, 1958, (22), 447–451) Tool steels, hard metal and ceramic tool wear are considered. The mechanism of chip formation and the course of wear is followed. Criteria for hard metals and ceramics are difficult to establish.

Inexpensive apparatus for interferometrically measuring thickness of electroplated chromium and other thin films R. L. Saur (*Plating*, 1958, **45,** Dec., 1232–1233). In the method described the equipment needed is a microscope equipped with vertical illumination, a monochromatic light source and a piece of optical flat glass laid on the specimen. Provided the surface is of near mirror quality thickness measurements are possible down to ·0001 in. without the use of a thickness standard.—A. G.

Magnetic-particle inspection paces production line at Griffin Wheel A. J. Panozzo (*Mod. Castings*, 1959, **34,** Feb., 38–40) A unit is described which was designed for the inspection of cast steel railroad car wheels by the continuous wet method of fluorescent magnetic particle inspection. The unit handles up to 60 wheels per h on a production basis.—T. G.

Magnetic flaw detection A. G. Gardner (*Metallurgia*, 1958, **58,** Dec., 309–312, 308) The principles governing the use of the magnetic particle technique are outlined, with some examples.

The role of the carbide phases and of primary ferrite in the formation of high-temperature cracking in the welding of austenitic steels N. F. Lashko and S. V. Lashko-Abakyan (*Avtom. Svarka*, 1958, **11,** (9), 99–110) This article is not concerned with the thermal effects of welding on cracking, but with the influence of alloying elements, viz. their influence on the change in the crystallization temperature range of austenitic steels; on the appearance of metastable, readily fusible eutectics, which are distributed between the dendritic axes and along the grain boundaries; on primary grain size; and on the formation of δ-ferrite. These influences should be considered jointly, not severally. The various alloying elements are classified according to their chief functions, and special attention is devoted to Si. It is concluded that the intermetallic phases play little part in the formation of cracks, which is primarily dependent on the carbide and boride phases. Special consideration is given to the carbide phases. Lastly the favourable influence of the primary ferrite phase is considered.—M. T.

Some remarks on the embrittlement of 18/8 and 16/13 Cr-Ni steels A. Zapletálek (*Zváranie*, 1958, **7,** (9–10), 298–300) [In Slovak] An account is given of recent researches on the formation of sigma phase, carried out at the Czechoslovak Welding Institute.—P. F.

Reducing rejects for hardening cracks P. P. Zuev (*Metallurg*, 1958, (11), 34–37) At the Elektrostal plant the main steel prone to hardening cracks is of the pearlite-martensite and martensitic class. When the rolled product is rapidly cooled, the transformation of austenite in the pearlite transformation zone cannot proceed, and martensite is formed. The resulting stresses cause cracking. At the Electrostal plant, metal is slowly cooled from 700 to 900°C in unfired pits. Rounds and squares up to 4 in. are cooled in the unfired pits but coiled material is usually cooled in heated pits. The optimum conditions to reduce cracks were: charging at not less than 650°C and cooling for not less than 24 h when the metal should be discharged at temperatures not over 100°C and the metal should be cooled not later than 12 h after withdrawal.—R. S.

Some notes on strain-age embrittlement in mild steels S. Hasebe (*Sumi. Met.*, 1958, **10,** July, 155–166) Ageing at room temperature after cold-working caused brittle fractures in the flaring, flattening and bending tests of pipes, especially in low-C basic Bessemer rimmed steel high in N_2. Low-C Al-killed steels, with 1·2–2·6 kg/t Al added in ladle and nozzle were analysed for acid-soluble Al and nitride content after forging and normalizing, and impact, impact-tension and tensile properties were measured. Brittleness appeared after slow cooling from above A_1 in both killed and rimmed steels.

The susceptibility of manganese structural steel to reversible temper-brittleness as a function of heat treatment N. Dragan and B. Rotenstein (*Studii Cercetari de Metalurgie*, 1958, (4), 463–476) Experimental results confirm that this steel is susceptible to this reversible temper brittleness although to a relatively smaller degree. This process occurs some time after exposure to the critical temperature. An extension of the time of holding of the steel at 500–550° and also at 700° reduces this susceptibility, but an extension of the time of holding at 450° has the opposite effect. At −100° the plasticity of this steel after hardening and tempering attains great values.

Static brittle-fracture initiation at net stress 40% of yield C. Mylonas, D. C. Drucker, and J. D. Brunton (*Welding J.*, 1958, **37,** Oct., 473–479) Laboratory experiments on unwelded steel plate produced brittle fracture, when tested in central static tension on pre-compressed plates with machined notches, at average net stresses well below yield level. The lowest average stress at fracture was 36% of virgin yield. The results are discussed.

The tendency of steel to reversible temper-brittleness in relation to the temperature of repeated austenitizing B. Rotenstein and N. Dragan (*Studii si Cercetari de Metalurgie*, 1958, (3), 259–286) [In Rumanian] Experiments have proved that the overheated steel tempered at high heat can be regenerated, with a fresh heat treatment, from the recrystallization temperature of the austenite originally overheated. The steel investigated (0·25%C; 1·15%Mn; 1·07%Si; 1·33%Cr) heat-treated under the conditions of the experiments, has a recrystallization point for austenite between 950–1000°C. The secondary austenitizing at the recrystallization temperature lowers the transition point from a fibrous break of the temper-brittle steel to a break of mixed appearance. The processes responsible for the brittleness of steel increase the unfavourable influence of grain growth on brittle failure.

Correlation of metallurgical properties and service performance of steel plates from fractured ships M. L. Williams (*Welding J.*, 1958, **37,** Oct., 445s–454s) It is shown that fracture initiation, propagation and ending were related to the combined effects of stress and notch-sensitivity at the operating temperature. A statistical study is made of the relation between notch-sensitivity and various other factors.

Evaluation of weld-joint flaws as initiating points of brittle fracture R. P. Sopher, A. L. Lowe jun., and P. J. Rieppel (*Ship Structure Committee, Project SR-131, Final Report: SSC–107*, 1958, Aug. 29, pp.51) Conditions for initiation for brittle fracture from flaws 4 in. long or less were studied. Residual and local stresses were found to join with applied stresses to make up the total involved in brittle fracture. With local stresses high near a flaw low applied stress might initiate fracture if the steel is at or near nil ductility temperature. The stress conditions used were those to be expected in a ship. Service failures and the results of this project show that flaws, especially cracks, of almost any size are potential initiators but that a total stress of yield-point value or higher, in conjunction with some stress-raising condition, is needed and that a combination of conditions must be present for the initiation of brittle fracture.

Ultimate resistance of plastic metals to brittle fracture G. V. Uzhik (*Vestnik Mashin.*, 1955, (6), 13–17) Examination of fractures in plastic metals has shown that in the majority of cases these fractures were not preceded by appreciable deformation. Brittle fracture of plastic materials can occur if, from whatever cause, from the time of the application of the load to the fracture, there is a partial or a complete inhibition of deformation. One such possibility is a reduction of temperature. But brittle fracture can also occur at room temperature because of an increase in the normal tensile stresses simultaneously with small increases in the existing low tangential stresses. Such conditions appear very often at places of stress concentration.—L. H.

Onset of brittleness in 20KhN1482 in ageing between 500–650° A. V. Tikhomirov, N. V. Sukhobokova, and N. A. Tikhomirova (*Metallov. Obra. Met.*, 1958, (8), 22–25) Specimens of this steel (approx. 0·08%C, 2·55%Si, 1%Mo, 20%Cr, 13%Ni) were investigated in their original condition, austenitized, and austenitized and stabilized. For ageing tests the specimens were divided into two lots, one quenched in water after heating for 15 min at 1100° and the other stabilized for 10 h after austenitizing. Ageing tests were carried out at 500°, 550° and 650° for 100, 500 and 1500 h. Ageing between 500–600° develops the tendency to brittleness and as a consequence plastic properties and in particular impact strength are reduced. The most appreciable fall in impact strength occurs in the first 200–300 h. Stabilization has little influence on ageing.

Effects of chemical composition on cracking resistance of high-strength steel weld metals

R. P. Sopher (*Weld. J.*, 1958, **37**, Nov., 481s–492s) The effects of C, S, P and rare-earth metals on cracking resistance have been studied. Phosphorus is considered responsible for low ductility and the cracking of welds at temperatures near the solidus. A new method for determining the causes of cracking in weld metals is described.—A. G.

The effect of boron on the tendency of heat-resisting austenitic steels of the 13Cr–18Ni–2W type to the formation of high-temperature weld cracking A. V. Russiyan and M. Kh. Shorohorov (*Svarochnoe Proizvodstvo*, 1958, (10), 14–18) Increasing the B content in such steels from 0–0·015% reduces the temperature at which a sharp drop occurs in the heat-affected zone from 1150 to 1010°C and extends the brittle temperature range owing to the precipitation of B compounds along the grain boundaries under the rapid heating conditions typical of welding. The dispersion energy of the arc should be restricted by suitable parameters, as this is liable to promote the distribution of B compounds along the grain boundaries and impair the plastic properties of the heat-affected zone. The above steel is more prone to cracking than 18Cr–9Ni steel. The tendency to cracking was reduced by a B content in the flux greater than 0·005%; the flux composition markedly affects the degree of transference of B to the weld metal.—M. T.

Pressure vessels and the problem of brittle fracture H. Harris (*Metallurgia*, 1958, **58**, Nov., 213–217) A report of the Presidential Address to the West of Scotland ISI, in which the present state of research into and knowledge of the problem of brittle fracture at low stresses was discussed.

Study of hydrogen embrittlement of iron by internal-friction methods R. E. Maringer, E. B. Swetnam, L. L. Marsh, and G. K. Manning (*NACA TN* 4328, 1958, Sept., pp.62) The effects of electrolytic charging on wires of relatively pure iron (Ferrovac E), and a 4340 aircraft-quality steel were examined metallographically and by reverse-bend internal friction testing from −196 to +430°C. The dependence on amplitude was large apparently due to domain boundary movement and hydrogen interaction with dislocations. The effects of a.c. or d.c. magnetic fields were also observed. Severe structural damage was demonstrated with blistering and internal cracking and internal friction peaks in both iron and steel were found at −150° to −120°. Glow discharge introduction of H_2 was also used and an attempt to charge Ta electrolytically was made. Much of the behaviour can be accounted for in terms of magnetoelastic energy losses (38 references).

Cadmium embrittlement of high-strength steels at elevated temperatures B. Cohen (*Plating*, 1958, **45**, Nov., 1127–1132) Trials on SAE 4340 steel are reported, and also on SAE H-13. The embrittling effect of molten Cd is practically instantaneous through penetration of the stressed metal. This is distinguished from embrittlement by H_2 after Cd plating.

The coefficient of dry friction of metals R. Takagi and Y. Tsuya (*J. Mech. Lab. Japan*, 1958, **4**, (1), 40–41) [In English] Abstract of a paper on the static friction of clean metal surfaces, the removal of any oxide films *in vacuo* or in a hydrogen atmosphere and the determination of the friction coefficients in air, vacuum, and hydrogen.—T. G.

The effect of heat treatment on the improvement of the resistance to wear of cast iron S. Koreyl and J. Rutkowski (*Prz. Odlew.*, 1958, **8**, Jan., 2–8) Both laboratory and industrial tests proved that a considerable improvement of the resistance to wear is obtained after cast iron is heat treated. Quenching with isothermal transformation has proved to be the most advantageous process.

Influence of heat treatment on the wear resistance of steels for earth working N. M. Serpik and M. M. Kantor (*Metallov. Obra. Met.*, 1958, (7), 46–50) Seven qualities of carbon steels were selected for investigation in a specially constructed stand reproducing as closely as possible actual conditions. Hardness alone cannot be accepted as a criterion since the heat treatment exerts an appreciable influence. Isothermal heat treatment gives a much higher resistance to wear for equal degree of hardness than can be obtained by the usual hardening with subsequent tempering.

Investigating the wear resistance of steel to friction with Capron fibre P. T. Basko (*Metallov. Obra. Met.*, 1958, (12), 56–57) Five types of steel were tested in abrasion with Capron fibre. The abrasion was found to be proportional to the pressure applied and the length of the operation whilst the speed of abrasion at a rate of between 10 and 70 m/min had no appreciable effect.

Investigating the influence of the condition of the surface layer of steel on its wear-resistance P. I. Ignatenko and Yu. S. Terminasov (*Vestnik Mashin.*, 1958, (12), 10–12) Tests were carried out on specimens of U8 steel annealed in an electrical vacuum furnace. They were then abraded at speeds between 30 and 50 m/sec to obtain deformations of varying degrees. From a number of specimens the deformation was removed by another electrical vacuum annealing. Friction experiments were then made at a constant speed of rotation under a 3 kg load for dry friction and under 20 kg for friction with a lubricant. Results obtained are tabulated, they show, of course, that the hardened surface is more resistant to wear.

The equilibrium between sulphur in molten iron and H_2–H_2S gas mixture. Thermodynamic studies on sulphur in molten iron. I A. Adachi and Z. Morita (*Tetsu to Hagane*, 1958, **44**, June, 637–642) The equilibrium was studied in the range 1550–1750°C and for concentrations up to 5%S, using a carbon-tube resistance furnace and a gas-bubbling technique. Equations are derived for the equilibrium constant and free energy change, which agree with Chipman only below 1600°C. An equation for the activity coefficient of S in molten iron is also given (15 references).—K. E. J.

Abrasive wear of steels in reciprocating-rotary movement R. M. Matveevskii (*Vestnik Mashin.*, 1958, (5), 31–35) An apparatus is described for measuring the abrasive wear of steel specimens subjected to reciprocating-rotary movement, with a controlled supply of abrasive. Results are given for a number of steels hardened at various temperatures.

The wear of gear teeth. VII. The mechanism of the phenomenon of incipient pitting (2) K. Ishida, H. Yamamoto, and T. Muta (*Rep. Gov. Ind. Res. Inst. Nagoya*, 1958, **7**, Dec., 879–884) Optical and electron microscopy was used to follow the development of wear. The convex surface was seen to transfer material to the coneave part and this layer was work-hardened. **VIII. (3).** (1959, **8**, Jan., 1–6) Three theories of failure are tested by calculation of stress values. The position of the pitting crack corresponded with depth of maximum stress obtained from the maximum shearing stress theory and the relation between shape of pit and tangential surface force is discussed. The intensity of this force is shown greatly to affect crack propagation rate, principal stresses and shear stress under the surface of the rolling disc. Calculations for 0·1 and 0·5 coefficient of friction are carried through as examples.

Test on the wear by friction of N12E steel files J. Klazynski and J. Zysk (*Prace Inst. Mechaniki*, 1955, **5**, (15), 1–20) The effect of the geometry of the cutting edge and of the temperature of hardening on the wear of files have been investigated and the experimental results are discussed.

Wear of carbon steel weld metal. I. Microscopical observations on the structural altered layers of the worn surface S. Ito, K. Honda, and K. Ishiyama (*J. Mech. Lab.*, 1958, **12**, Sept., 150–157) The taper sectioning method and microhardness testing were used to examine the surface layers altered by dry friction. There are three types, the oxide layer, the heat-transformed layer and the ruptured-grain layer, the worn surfaces have complex combinations of these types. The oxide layer is grey in 2% alcoholic HNO_3 and the heat-transformed layer yellow or brown. The latter often has a laminar structure.

The anti-frictional properties of high-strength spheroidal graphite cast iron A. P. Antonov (*Vestnik Mashin.*, 1958, **38**, (10), 37–40) Cast-iron of composition 3·39%C, 2·41%Si, 0·65%Mn, 0·009%S, 0·07%P, 0·05%Mg, prepared in an induction furnace by treatment with a 15%Mg–10%SiCa–75%FeSi alloy, was compared with 5–5–5 bronze anti-frictional cast and forging irons and Cementite steel 20 (heat treated). The SG iron was tested in five forms: after normalization and after isothermal hardening at 250, 300, 350 and 450°C. The coefficients of friction, dry and with lubrication of the SG iron in all states of heat treatment was less than that of all the other materials except the 5–5–5 bronze.—M. T.

The nature of the wear protection of mild steel caused by phosphating J. W. Midgley and H. Wilman (*Institution of Mechanical Engineers. Conference on Lubrication and Wear, London*, 1957, 230–236) The surfaces are etched into a network of channels 0·0004–0·0008 in. deep with phosphate crystals on the high spots. Running in is rapid and low-friction conditions are soon established. The channels serve to supply lubricant, to let out debris and prevent extensive welding, the phosphate is soon removed with decrease of friction. Tests up to 4000 lb/in² are described. **A review of the friction of solids with particular reference to the Conference papers** F. P. Bowden (239–245). **Experimental check of elementary law of friction: Dry friction** I. V. Kraghelsky and V. P. Sabelnikov (246–251). An optical method with transparent samples is described. **A theory of stick-slip sliding of solids** B. V. Derjagum, V. E. Push, and D. M. Tolstoi (257–268) Formulae are derived for conditions under which vibrations due to stick-slip disappear and methods of securing these conditions are given. The sticking stage is analysed and the variation of maximum sliding velocity in the course of stick-slip vibrations is illustrated. **The friction and wear of various materials sliding against unlubricated surfaces of different types and degrees of roughness** R. T. Spurr and T. P. Newcomb (269–275) Steel, eight other metals and three plastics were measured against emery paper, files and emery-abraded steel rods. Different mechanisms were observed in the three cases, the wear on files being related to metal elasticity and to angle of inclination of the teeth but on the abraded rods the laws were different. **Investigation of size effects in sliding by means of statistical techniques** E. Rabinowicz (276–280) Size and distribution of junctions between sliding metals are derived. **Probable behaviour of contacts in the sliding process** B. G. Rightmire (281–285) Probability analyses are applied to published results and uses of the method are suggested. **Metal transfer in boundary lubrication and the effect of sliding velocity and surface roughness** L. Grunberg and K. B. Campbell (291–301) Sliding of copper on steel is examined by the use of tracer methods. The increase of friction at lower sliding velocities is attributed to transient creep of copper in strained regions. **Calculation of dry friction forces** I. V. Kraghelsky (302–307) Mechanisms are examined on the microscale and a relationship to surface waviness is proposed. **On preliminary displacement** V. Shchedrov (308–313) Slipping of materials under tangential forces is preceded by a preliminary displacement made up of reversible and irreversible components. A solution is found for elastic-plastic contact assumed to be heterogeneous and an expression for the relation of the preliminary displacement to retardation time. **The properties of model friction junctions** J. A. Greenwood and D. Tabor (314–317) A two-wedge model is used of non-ferrous metal. **Vapour lubrication and the friction of clean surfaces** G. W. Rowe (333–338) Studies in a high vacuum and in presence of vapours are reported. Reference surfaces were produced by evaporation of appreciable quantities of the surface and friction is then high even for the hardest materials. Very small quantities of vapours, especially fatty acid vapours, prevent seizure, and this is assisted by traces of O_2 and water MoS_2 on Mo, TiI_2 on Ti and $CrCl_3$ on Cr are very effective. **Orientation and frictional behaviour of lamellar solids on metals** R. F. Deacon and J. F. Goodman (344–347) Graphite and MoS_2 on Pt are studied. **Friction and lubrication with solid**

lubricants at temperatures to 1000°F with particular reference to graphite E. E. Bisson, R. L. Johnson, and W. J. Anderson (348–354). **A review of the papers on bearing materials, solid lubricants, surface treatments, and glands and seals** P. P. Love (361–365). **Compatibility testing of bearing materials** E. R. Booser, E. H. Scott jun., and D. F. Wilcock (366–370). **Wear of selected molybdenum disulphide lubricated solids and surface films** D. C. Mitchell and B. B. Fulford (376–383) Plastics and steel-backed bronze were used. **Friction, wear, and surface damage of metals as affected by solid surface films: A review of NACA research** E. E. Bisson, R. L. Johnson, and M. A. Swikert (384–391) Beneficial effects were observed with graphitic carbon on cast iron and FeO and Fe_3O_4 on ferrous materials, but Fe_2O_3 and MoO_3 were detrimental. FeS and $FeCl_2$ films prevented surface welding and $FeCl_2$ reduced friction more effectively. MoS_2 was shown to go to MoO_3 in air. **The wear of PTFE impregnated metal bearing materials** D. C. Mitchell (396–404) Polytetrafluoroethylene compositions were tested. **Friction, wear and physical properties of some filled PTFE bearing materials** D. C. Mitchell and G. Pratt (416–423). **Some studies of pitting failure in rolling contacts** A. A. Milne and M. C. Nally (459–462) A modified four-ball machine was constructed for high speeds using balls or cones. **Study of the effect of lubricant on pitting failure of balls** D. Scott (463–468). **Influence of magnetic fields and the passage of electrical currents on the deterioration of ball bearings** F. F. Simpson and R. W. Russell (477–481) Under practical conditions the effect of magnetic fields is probably negligible. Direct currents of as little as ½ amp may cause damage in 24 h. **Load-carrying additives for steam turbine oils** J. S. Elliott and E. D. Edwards (482–491) The development of an oil resistant to foaming, emulsification and stability is presence of water is described with comparisons of extreme-pressure testing machines. **Control of wear in piston engines** J. A. Edgar (498–504). **Liquid sodium as a lubricant** R. B. Campbell (529–533) Tests on stainless steel rings in N_2 at 20 ft/min at 100–200°C are described. **Influence of acidity of the lubricating oil on the wear and deposits obtained in the Caterpillar 1A oil-test engine** R. Tourret and R. W. Bale (539–542). **A report of the papers on wear** F. T. Barwell (587–601). **The embedment of abrasive in lapped surfaces** K. J. Williams (602–605) A tracer study of particle retention in hand-lapped surfaces of tool steel, Mo-sprayed mild steel and non-ferrous materials is reported. **The electron microscope in the study of wear** D. Scott and H. M. Scott (609–612) Replicas were prepared and interpreted and sub-surface examination and wear debris study are also briefly considered. **Nature of the wear and friction of mild steel on mild steel and the effect of surface oxide and sulphide layers** M. R. Piggott and H. Wilman (613–619) **Recent developments in the theory of elastic contact stresses: Their significance in the study of surface breakdown** K. L. Johnson (620–627) Theory is reviewed (27 references). **Plastic roughening and wear** I-Ming Feng (635–639) The effect of various factors including surface contamination and crystallographic orientation are evaluated and the 'running-in' phenomenon and the damage to a hard sliding member by a soft one are discussed. **Application of reflection electron microscopy to the study of wear** J. S. Halliday (647–651) Some confirmation is found for the idea that the asperities producing wear on smooth surfaces may be below the limit of resolution of the optical microscope. **Wear and friction of metals at very high speeds** E. H. Freitag (652–654) Speeds up to 1000 m/sec were studied and the phenomena observed are outlined. **Resistance of metals to wear by abrasion as related to hardness** M. M. Khruschov (655–659) A testing machine is described and Fe, two steels and eleven other metals were examined. The hardness of the metals is related to wear as is the hardness of the steels after heat treatment. **Structures produced by surface deformation** L. Grunberg and K. H. R. Wright (660–669) Examinations of rock salt and Al for dislocations and vacancies in the deformed surface layer is described. **Optical microscopy in wear studies** D. Scott (670–673) Interferometric, replica and sectioning techniques are reviewed. **Wear of unlubricated metals** W. Hirst (674–681) A review. Severe wear results from intermetallic welding in two cases which operate by different mechanisms. Wear rates are proportional to load except at higher speeds with heavy loads where the surface temperature rises. For severe wear, increased hardness reduces the degree produced. Comparison is made with current theory and application to practice is discussed. **New method for studying freshly deformed surfaces** L. Grunberg and K. H. R. Wright (682–688) A photoelectric emission method is used on Al, Mg and Zn. **Destruction of cast iron surfaces under conditions of dry sliding wear** H. T. Angus and A. D. Lamb (689–693) Conditions on brake drums and clutch plates are considered and three mechanisms leading to failure are set out. Effects of pearlite, ferrite and graphite, flake or nodular are briefly noted and the phenomena of oxidation of such surfaces are described. **Severe metallic wear** J. K. Lancaster (694–700) Experiments at low rates of sliding are reported intended to minimize changes in surface conditions which are supposed to account for the deviation from the values calculated from theories of the wear process. The specimens were non-ferrous and covered a wide hardness range. **Structural changes in rubbed steel surfaces** N. C. Welsh (701–706) Structural effects of high frictional temperatures in dry or imperfectly lubricated rubbing and its effect on wear resistance and on metal cutting are considered. With good lubrications only plastic strains develop. **Wear of lubricated journal bearings** W. E. Duckworth and P. S. Forrester (713–719). **Some studies of scuffing with a crossed-cylinder machine** A. A. Milne, D. Scott, and D. Macdonald (735–741) Soft and case-hardened steels were examined by various methods including replica electron microscopy. The sequence of events during the passage of a single contact over a surface is established.

The role of grains in the cavitation-erosion failure of steel I. N. Bogachev and R. I. Mints (*Metallov. Obra. Met.*, 1958, (8), 26–29) 0·4%C, 0·8%C and 1·2%C steels were tested on an impact–erosion machine with the specimens rotating at 78 m/sec under a water pressure of 0·28 atm, nozzle distance 1·4 mm. Resistance is found to depend on grain size, nature of grain boundaries, and on the intergranular structure.—L. H.

Severe wear of pearlitic steel weld metal S. Ito, K. Honda, and K. Ishiyama (*J. Mech. Lab. Japan*, 1958, **4**, (1), 15–21) [In English] Wear tests were carried out on hard-faced welds in a study of the wear mechanism of these welds. About 40 different hardfacing-electrode materials were examined. From the wear and microscopical tests and from the movement of the wear debris it was concluded that annealed welds show better wear properties than those in the as-welded state.—T. G.

A range of ferrous alloys to combat abrasion, corrosion and heat H. G. Horrell (*South African Mech. Eng.*, 1958, **8**, Nov., 89–116) Mining and ore treatment materials are considered – metals for grinding are tabulated and tables of alloys resisting abrasion, corrosion and heat are given, especially in the form of castings. The processes of melting, casting, rolling and forging, and machining are briefly outlined.

Directional dependence and polarization of radiation from liquid iron and steel W. Pepperhoff (*Arch. Eisenhut.*, 1959, **30**, March, 131–135) The proportion of polarised radiation from metals increases steeply with increasing angle; the polarization of metal radiation is impressively demonstrated if the surfaces of iron and steel melts are observed with a polarization filter at an oblique angle. Oxidized melt surfaces emit unpolarized radiation at all angles: observation under polarized light therefore provides better differentiation of surface structure than under natural light.

Penetrant testing T. De Forest (*Nondestr. Test.*, 1958, **16**, July–Aug., 333–337) A review of methods and materials commonly used in penetrant testing. A chart lists the variables in operating conditions and a number of photographs show typical applications.—T. G.

Magnetic flaw detection A. G. Gardner (*Metallurgia*, 1958, **58**, Nov., 257–259) The principles underlying the magnetic particle method of detecting flaws in iron and steel parts are discussed.

Effect of cooling rate from Ms temperature to room temperature on magnetic properties of 3·5% chromium magnet steel W. L. Hodapp and E. A. Loria (*Trans. ASM*, 1958, **52**, preprint 122, pp.13) The rate of cooling had an effect on the magnetic properties apparently due to retained austenite.

Magnetic analysis of liquid iron-based alloys A. A. Vertman and A. M. Samarin (*Izvest. Akad. Nauk, Otdel. Tekn.*, 1958, **10**, 100–103) Due to the thermodynamic method of investigation of real solutions considerable knowledge about their behaviour has been gained, nevertheless, the problem of physical reasons for deviations from ideal behaviour of alloys remains unsolved. Structural methods of investigation, namely the X-ray and the electronographic methods, used for testing thin liquid films have also certain disadvantages. The authors carried out their research by measuring susceptibility (χ) of liquid alloys by the Faraday method, using an apparatus described earlier. Three liquid alloys: Fe–Si, Fe–Co, and Ni–Co were tested at a constant temperature, 1600°C, in an atmosphere of argon; the intensity of the magnetic field was kept strictly constant. Graphs of χ as a function of composition were plotted. Interesting results concerning the formation of Fe–Si compounds and the structure of these three alloys were obtained.—S. S.

Magnetocrystalline anisotropy constants of iron at room temperature and below C. D. Graham jun. (*Phys. Rev.*, 1958, **112**, Nov. 15, 1117–1120) Measurements at 77°, 195° and 300°K are reported.

Study on ultra thin strips of 50% Fe–Ni alloy. I. Relation between the magnetic properties and the rolling condition of the strip E. Tanaka and H. Kato (*Nippon Kinzoku*, 1957, **21**, Nov., 651–654) Magnetic properties of strip thicker than 0·025 mm were improved by decrease in thickness, but those of strip thinner than 0·0125 mm were reduced. These results arise not from surface contamination but from the actual thickness.—K. E. J.

An apparatus for magnetic anisotropy analysis B. B. Timofeev (*Elektrichestvo*, 1957, (5), 72–74) An accurate and rapid, non-destructive method of determining magnetic anisotropy in metals is described, and the theoretical basis is outlined for the apparatus described.—M. T.

Change of the magnetic structure of the crystals of silicon iron under elastic stresses V. A. Zaikova and Ya. S. Shur (*Izvest. Akad. Nauk Seriya Fiz.*, 1958, **22**, (10), 1185–1189) Under elastic stresses the boundaries are displaced, the dimensions of the subsidiary and interlocked domains change, the type of magnetic structure changes. These changes depend on the magnitude of the stresses, on the original structure and on the direction of the stress relative to the crystallographic axes. The changes in structure are irreversible.

The influence of heterogeneity of ingots of soft magnet steels on the absolute values of the coercive force and on magnetic ageing T. Prnka, L. Kodrle, J. Wozniak, and V. Foldyna (*Hutnik*, 1958, **8**, (8), 269–272) [In Czech] Data obtained from the literature and from experiments carried out by the authors are used to show that soft magnetic material equivalent in properties to the best foreign products can be obtained by the utilization of the bottom ends of ingots of all effervescent steels in so far as their composition lies within the limits prescribed by standard specifications. Apart from nitrogen, oxygen also affects the magnetic properties of the metal.—F. F.

An investigation of the influence of temperature on the magnetic properties of electrotechnical steels O. N. Al'tgauzen (*Elektrichestvo*, 1958, (6), 80–82) Specimens taken from electrical steel sheets (two hot-rolled and one cold-rolled) were tested to show the influence of heating to 300°C and cooling to −78°C on their induction and magnetic permeability in fields with an intensity of 125 oersteds.—M. T.

The recrystallization and magnetic properties of Armco iron Tai Li Chi (*Acta Met. Sin.*, 1958, **3,** (3), 227–230) X-ray pole figure and magnetic torque methods were used. Samples with higher magnetic permeabilities show secondary recrystallization. The relations between these are discussed.

Dynamics of the domain structure in crystals of transformer steels under stress L. V. Kirenskii, M. K. Savchenko, and A. M. Rodichev (*Izvest. Akad. Nauk, Seriya Fiz.*, 1958, **22,** (10), 1181–1184) By means of the powder figures of Akulov (*Ann. Phys.*, 1932, **15,** 750) and of Bitter (*Phys. Rev.*, 1931, **38,** 1903; 1932, **41,** 507) the elastic stresses of the domain structure of crystals of transformer iron (3·4%Si) were investigated. It was shown that under stress the structure changes and that the nature of the change depends on the stress applied. The experiments were carried out along the three crystallographic axes and graphically recorded. Along [001] the initial steep rise of the curve is due to the elimination of the surface domains and the intensive displacement of boundaries between domains during the evening out of their widths. Along [110] the initial part of the curve is due to the destruction of the original structure under the action of the stress. Along [111] the path of the curve is almost linear for loads up to 22 kg/mm² over this interval the domain structure does not change except for a parallel displacement of boundaries and elimination of surface domains.

Studies on the magnetic properties and the microstructure of high-C high-Cr permanent magnet steel K. Tachikawa (*Nippon Kinzoku*, 1957, **21,** Dec., 689–693) Changes in magnetic properties and microstructure of the steel caused by various heat-treatments were investigated. The best magnetic properties were obtained by primary heating at 600–900°C followed by air-cooling from 1060°C; this reduces the quantity of retained austenite and promotes pptn. of fine carbides. The magnetic effects are discussed in terms of microstructure.

The magnetic structure of Fe_3Al R. Nathans, M. T. Pigott, and C. G. Shull (*Phys. Chem. Solids*, 1958, **6,** July, 38–42) Al has no magnetic moment and the iron atoms occupy two lattice sites with different moments.

Magnetic property and crystal chemistry of ilmenite ($MeTiO_3$) and haematite (α-Fe_2O_3) system. II. Magnetic property Y. Ishikawa and S. Akimoto (*J. Phys. Soc. Jap.*, 1958, **13,** Nov., 1298–1310) [In English].

Magnetic structure of Fe_4N B. C. Frazer (*Phys. Rev.*, 1958, **112,** Nov. 1, 751–754).

Magnetostriction of nickel-iron-molybdenum alloys I. M. Puzei and B. V. Molotilov (*Izvest. Akad. Nauk, Seriya Fiz.*, 1958, **22,** (10), 1244–1250) Measurements were carried out with a bridge, in all four arms of which tensometers were inserted (50, 150 and 100 ohms). Two arms were arranged for measuring, the two others for compensating. All were mounted on one block placed in a vacuum vessel, ensuring even temperature. Since the alloys investigated lay in the region of zero magnetostriction of the order of 10^{-6}–10^{-7}, the simple bridge did not provide sufficient accuracy. In the indicator arm a photo-amplifier was inserted. Heating was carried out to 1100° for 3 h followed by quenching from 600° in oil. The cooling was by stages from 480° in 540 h. The monocrystals were investigated along the [100] and [111] axes and the findings are tabulated graphically.

Volume magnetostriction of iron-nickel-molybdenum alloys I. M. Puzei, B. V. Molotilov, and A. I. Rad'kov (*Izvest. Akad. Nauk Seriya Fiz.*, 1958, **22,** (10), 1251–1253) The alloys were heat-treated in two ways: heating to 1100° for 3 h, cooling to 600°, then quenching in water; and heating to 1100° for 3 h and cooling by stages from 500 to 300° during 54 h. The relation between magnetostriction and the field in the alloys after prolonged annealing and after quenching is given graphically, similarly that between magnetostriction and temperature.

The influence of composition and structure on the electrical resistance of cast iron J. Hrubý (*Slévárenství*, 1958, **6,** (8), 248–253) [In Czech] The electrical conductivity of cast iron used for resistance elements in circuits for the control of electric motors is known to depend upon the structure and composition of the metal. In the present work an experimental study showed that the silicon content of the metal and the moisture content of the mould mixture are most important variables in relation to the specific resistance of the cast iron. Size effects were also found. Pouring temperature and Mn and P contents did not affect the specific resistance appreciably.—P. F.

On the temperature coefficient of co-elinvar (Fe–Co–Cr–Ni alloy) vibrators H. Masumoto, Y. Shirakawa, and I. Oguma (*Nippon Kinzoku*, 1958, **22,** Mar., 117–120) Co-elinvar of composition 34–38%Co, 5–11%Cr, 16%Ni, balance Fe, has a frequency temperature coefficient in the region 10^{-5} to 10^{-6}. Alloy having a composition within this range can be mass-produced. Such an alloy is suitable for constant-frequency mechanical vibrators, high frequency mechanical filter elements, and springs for precision apparatus.—K. E. J.

Tube testing gains precision (*Steel*, 1958, **143,** Oct. 13, 104–106) A description is given of the 'Fanowtest', an instrument developed by Republic Steel for detecting flaws in welded steel tubing both carbon and stainless. The test depends on eddy currents induced in the tube and, for example, can detect flaws down to 0·003 in² in area in tubes with 16 gauge wall thickness.—A. G.

Thermodynamic properties of Cu–Ni and Fe–Co solid solutions Ya. I. Gerasimov, A. A. Vecher, and V. A. Geiderikh (*Doklady AN*, 1958, **122,** (5), 834–836) By the method of electromotive forces the authors have determined free energy, heat and enthropy of formation of Cu–Ni alloys and the activity of iron in Fe–Co alloys. The results presented in diagrams are discussed in detail.—S. I. T.

Sources of defects located by non-destructive testing C. E. Betz (*Nondestr. Test.*, 1958, **16,** July–Aug., 319–332) A lecture dealing with the origin of the defects detected by non-destructive testing. The defects are classified on the basis of the progress of material from its raw state to the finished form as: (*a*) inherent defects; (*b*) processing defects; and (*c*) service defects.—T. G.

The limit of application and possible development of non-destructive methods for testing materials I. Malecki (*Prz. Techn.*, 1958, **79,** March, 170–175) The author gives a brief review of the conclusions arrived at at the Second World Conference of NMT in Chicago in 1957. He surveys the limit of application of the various apparatus in use.

A new method of increasing productivity in ultrasonic treatment A. I. Markov (*Vestnik Mashin.*, 1958, (12), 46–47) The author has combined two processes, one, the anodic saturation of a specimen with H_2, which induces brittleness, and the other, removing it by ultrasonic treatment. The materials investigated included quenched steel, heat-resistant alloys and heavy alloys. A description of the apparatus is given and the results tabulated. These show the advantages of the combined process which reduces the wear of tools by factors of between 2 and 4·5.

Constitution and magnetic properties of iron-rich iron-aluminium alloys A. Taylor and R. M. Jones (*Phys. Chem. Solids*, 1958, **6,** July, 16–37) The range 0·62 at % Al was examined by X-ray diffraction and significant differences from the diagram of Bradley and Jay were found. A phase change was found in the Fe_3Al region with rise of temperature. Magnetic and other anomalies are interpreted in the light of these changes. A ferromagnetic face-centered cubic phase was also found in the 10–33 at % Al range, probably a carbide.

A reference wedge X-ray gauge S. Bernstein (*Nondestr. Test.*, 1958, **16,** July–Aug., 305–312) A new X-ray gauge is described which has a high stability and is very simple and versatile. It is of the ion-chamber type, the standard sample is, however, a rotating wedge. The advantages of using a rotating wedge are stressed; block diagrams and a description of the servo design are included.—T. G.

Radiographic determination of elastic internal stresses in casehardened and nitrided parts H. Hasenmaier (*Hart. Techn. Mitt.*, 1958, **12,** (2), 23–37) The principle underlying the radiographic measurement of elastic stresses is outlined, and the application of the method to the determination of internal stresses in carburized and nitrided parts is described.

An electron probe for local analysis by means of X-rays D. B. Wittry (*Interim Tech. Rep. No. 5 Dept. of Army Project No.* 5B99–01–004, 1957, April, pp.188).

Saturation magnetizations of iron carbides L. J. E. Hofer and E. M. Cohn (*J. Am. C.S.*, 1959, **81,** Apr. 5, 1576–1582) The measurements were made for purposes of these determinations in steels and irone atalysts. The paramagnetic movements of χ-carbide and cementite were 5·55 and 3·89 Bohr magnetons.

A contribution to the quantitative study of magnetic lag in the diffusion of carbon in α-iron P. Brissonneau (*J. Phys. Chem. Solids*, 1958, **7,** Oct., 22–51) [In French] A large after-effect is found in very dilute solid solutions of C in iron. Néel's theory is used to explain the effect which appears to offer a very sensitive method of determining dissolved impurities.

Intermittent effects of pile irradiation on the magnetic properties of a ferrite G. C. Bailey, E. I. Salkovitz, and A. I. Schindler (*Rept. NRL Progress*, 1958, *PB* 151333–125, Dec., 37–38) Radiation damage appears to occur early (in the first 2 h of irradiation) and recovery also appears to be rapid.

Magnetic losses at low temperatures E. H. Brown and J. R. Brennand jun. (*J. Appl. Phys.*, 1959, **30,** Jan., 112–114) Measurements on a Si-steel transformer core are made down to 20°K.

Two Hall effects of iron–cobalt alloys F. P. Beitel jun. and M. P. Emerson (*Phys. Rev.*, 1958, **112,** Dec. 1, 1516–1520).

Eddy current losses in 65/35 nickel-iron E. W. Lee, A. G. H. Troughton, and D. R. Callaby (*Proc. Phys. Soc.*, 1959, **73,** Jan. 1, 133–136).

Fermi-Thomas angular dependent potential for iron D. M. Hum (*Proc. Phys. Soc.*, 1959, **73,** Apr. 1, 650–660).

Ultrasonic testing procedures J. B. Morgan (*Nondestr. Test.*, 1959, **17,** Jan.–Feb., 32–36) A research programme carried through by Allegheny Ludlum is reported. Effect of alloy, distance of discontinuity below the surface, effect of heat treatment, size of discontinuity, direction of beam, nature of product and effect of reduction on working were varied and the findings with tool steels, and ferritic, martensitic and austenitic alloy steels are given. This work is being extended but a particle size effect was found which makes quantitative measurements difficult.

The influence of sonic interference patterns in the detection of defects in solid bodies F. Linhardt (*Metall*, 1958, **12,** Dec., 1085–1092) The necessity for ascertaining the structure of the sonic field produced in front of the ultrasonic transmitter is emphasized, and an experimental method described for determing by a combined optical and acoustic technique the interference patterns formed behind a slit. The significance of the results in altrasonic testing is discussed.

Ultrasonic weld inspection J. E. Bobbin (*Nondestr. Test.*, 1959, **17,** Jan.–Feb., 26–28) The principles of testing, the formulation of specifications and costs are briefly considered. The general advantages of the method are summarized.

Nondestructive inspection of rails by means of ultrasonics M. Palme and M. Deutsch (**Revue Generale des Chemins de Fer*, 1955, **74,** 872–879) Portable equipment is also described.

Properties of ultrasonic waves when traversing metallic media. Case of cast iron and steel J. O. Martinez (*Inst. Hierro Acero*, 1958, **11,** Oct.–Dec., 263–281) The influence of structure and composition on the absorption, extinction and velocity of propagation of ultrasonic vibrations in metals is studied in the case of cast iron and steel. The principal anomalies are discussed.

The influence of the microstructure of steel on the damping of ultrasonic waves W. Rozanski and S. Madej (*Hutnik*, 1957, **24,** Nov., 452–457) [In Polish] The damping of ultrasonic waves in solids and the dependence

of the coefficient of damping on the microstructure of the medium are discussed. As a result of their own researches the authors propose to use this phenomenon of damping for the determination of the grain size and possibly of the content of carbon in the steel.

Microbeam analysis of Widmanstätten structure in meteoric iron R. E. Maringer, N. A. Richard, and A. E. Austin (*Trans Met. AIME*, 1959, **215,** Feb., 56–58) An account is given of a study of the concentration and distribution of Fe and Ni in the various phases of meteoric iron, using an electron-probe analyser.

Practical planning for non-destructive testing by use of radiation F. S. Sutherland (*Mod. Castings*, 1959, **34,** Jan., 71–75) The most commonly used equipment employed in radiographing metal in foundries consist of portable 250-kV, 1000- or 2000-kV X-ray units or a betatron. The choice of the source or unit and the problems connected with it is discussed.

Physical-technical principles of radiation protection in non-destructive material testing J. Zakovsky (*Schweisstechn.*, 1958, **12,** Dec., 157–161) By the use of tables, examples are worked out for protection against X-radiation and radiation from isotopes.

Electron diffraction study of tempered low-carbon martensite B. S. Lement (*Trans. Met. Soc. AIME*, 1959, **215,** Feb., 163–164) The electron diffraction measurements described provide evidence, not however conclusive, that the only carbide phase formed during the tempering of a 0·15%C martensite is cementite. Results tend to support the hypothesis of Roberts (*ibid.*, 1953, **45,** 576) that cementite rather than ε-carbide is formed during tempering if the C content of the martensite is below about 0·25%.

Electron diffraction study of ferromagnetic inclusion in austenitic stainless steel S. Yamaguchi and Y. Aoyama (*Anal. Chem.*, 1959, **31,** Feb., 318–319) An application of the Lorentz effect by which the rings due to magnetic impurities are not concentric with those of austenitic steel is described.

Radiation damage of metals J. R. Hawthorne and L. E. Steele (*Rept. NRL Progress*, 1957, *PB* 151344 125, Jan., 30–32) Charpy V-notch tests on irradiated pressure-vessel steels were made by remote control. The modifications to the testing machine are indicated.

Influence of irradiation temperature upon state of order in 50—50 Fe-Ni alloy A. I. Schindler, E. I. Salkovitz, and G. S. Ansell (*Rept. NRL Progress*, 1958, *PB* 151333–125, Dec., 36–37) Order was enhanced by rise of temperature during irradiation as shown by magnetic measurements.

Structural amplitudes for the neutron diffraction of cementite D. Meinhardt (*Arch. Eisenhut*, 1959, **30,** Jan., 51–53) The positions of the carbon atoms are especially discussed from the data of Lipson and Petch, and from more accurate data from neutron diffraction.

Low-temperature specific heats of body-centered cubic Cr Fe and Cr Mn alloys C. T. Wei, C. H. Cheng, and P. A. Beck (*Phys. Rev. Letters*, 1959, **2,** Feb., 95–96).

The effect of rapid heating on the specific heat curve of low carbon steel at the phase transformation points A. M. Nathan (*US Navy and US Air Force, Tech. Memo. NYU–6–M–P*; *PB* 131864–075, 1951, Mar. 13, pp.17) A dynamic method of sp. heat measurement at heating rates of ~ 1000°C per sec is described. Results on a standard SAE1040 steel with 0·4%C, 0·6%Mn annealed at 950° are given. The peak of the sp. heat curve usually occurring at A_1 is greatly affected by rapid heating but the anomaly at the Curie point is not affected.

On the heat treatment and high temperature strength of 2¼%Cr 1%Mo steels T. Kaneda (*Tetsu to Hagane*, 1958, **44,** Sept., 1083–1084).

High-temperature deformation of steels: A study of equicohesion, activation energies, and structural modifications C. Crussard and R. Tamhankar (*Trans. Met. Soc. AIME*, 1958, **212,** Dec., 718–730) The high-temperature deformation in tension, creep and torsion of Armco Fe and a low-C stable austenite – a 35 : 10 Ni–Cr steel – has been studied. The changes of structure produced by deformation were examined by micrography, X-rays and microfractography. The results are reported in detail and discussed (30 refs.).—T. G.

Engineering problems associated with low temperatures D. H. Tantam (*Eng. Mat. Design*, 1959, **2,** Feb., 72–76) Mild steels with 0·08%, 0·13% and 0·22%C and 18/10 stainless are included and mechanical properties at temperatures down to ~ 190°C are tabulated.

Physico-chemical reactions taking place in steels containing 18% chromium and 2, 4, or 6% nickel P. Bastien and A. Sulmont (*Rev. Mét.*, 1959, **56,** Jan., 40–48) Steels containing 18%Cr and 2–6%Ni are particularly suitable for studying, by dilatometric, microscopical and magnetic methods, the tempering of martensite and the formation of δ-phase. It was found that the diffusion of Cr and Ni in iron, which is less in austenite than in ferrite, governs the development of the structure.

Principles of high-energy radiography S. S. Stacey (*Nondestr. Test.*, 1958, **16,** July–Aug., 339–344) The author demonstrates that the change in the quality of radiation, i.e. from low-energy to high-energy, affects the quality of industrial radiographs and therefore the range of defect detection. The radiographer must choose the energy best suited to detect most or the most important defects in his objects.—T. G.

X-ray diffraction techniques in iron and steel research T. R. Thomson (*BHP Techn. Bull.*, 1958, **2,** Sept., 17–20) A survey of the application of X-ray diffraction techniques to structure determination, identification and analysis of crystalline compounds and X-ray spectrochemical analysis.

A contribution to the classification of casting defects and their identification in X-ray and gamma-ray tests E. Schiebold and E. Becker (*Giesserei-Techn.*, 1959, **5,** March, 81–84) The draft tables of defects in castings here presented are based on the system of classification presented by the author at the International Standards Conference on Industrial Radiography at Halle in 1958.—L. J. L.

The investigation of radioisotopes for the inspection of ship welds E. L. Criscuolo, D. P. Case, and D. Polansky (*Ship Structure Committee, Project SR-127: SSC-110, 1st Report* 1958, Feb. 28, pp.57) Inspection of ¼–2 in. plate was investigated using ^{170}Th, ^{192}Ir or ^{137}Cs. For ½–1 in. plate, Ir is the most promising. A portable exposure container for it has been developed.

Studies of surface layers of polished metals by means of electron diffraction and by electrical contact resistance measurements M. Matsunaga (*Rep. Inst. Ind. Sci. Tokyo Univ.*, 1958, **7,** Mar., 225–252) Effects of polishing and the nature of the chips produced were examined for stainless steel and non-ferrous metal. Diffraction patterns of electropolished steel and 18–8 stainless were used to identify the oxide. A graphite slide was used for the contact resistance measurements and measurements were made on cast iron, quenched steel, 13%Cr and 18–8 stainless steels as well as Cu and brass. Similar measurements were made on Cr plate.

Electron diffraction studies on the high temperature oxidation of Fe Al alloys. I. On the oxidation-resisting films T. Nakayama (*Nippon Kinzoku*, 1957, **21,** Dec., 716–720) Fine films of α- or γ-Al_2O_3 are formed on Fe–Al alloys and calorized steel oxidized in air at 700°C. These retard diffusion of metal atoms outwards and oxygen molecules inwards.

Differential elastic scattering of 14 MeV neutrons in aluminium, iron, lead and bismuth for large angles K. Yuasa (*J. Phys. Soc. Japan*, 1958, **13,** Nov., 1248–1258).

The effects of neutron irradiation on the ductile-brittle transition temperatures of weldable structural steel plates R. C. Burnett, J. M. N. Allen, and D. R. Harries (*AERE M/R* 2536, 1958, pp.28) A study of a welded Ducol W30 steel plate 4½ in. thick is reported. Specimens were irradiated in helium-filled cans to a total of 4×10^{19} and $7{\cdot}6 \times 10^{19}$ n/cm² and soaked at 60° or 140°C for 126 days to remove effects of the long-term heating. Bend and hardness tests were carried out and structures were observed. The temperature was found to be raised from 30–38°C at the lower and 70°C at the higher temperature and at the $7{\cdot}6 \times 10^{19}$ level to 75° at either temperature. Soaking of the control specimens at these temperatures for the same periods had no significant effect on the brittleness transition. Decreases of energies to fracture and increased hardnesses were produced.

Specific heat of a face-centered-cubic Mn–Fe alloy at liquid helium temperatures Chuan-Tseng Wei, Chin-Huan Cheng, and P. A. Beck (*Phys. Rev.*, 1958, **112,** Nov. 1, 696–698).

Dilatometers for metals and alloys R. S. Mints (*Zavods. Lab.*, 1958, (12), 1526–1528) Descriptions are given of three special types of dilatometer of simple construction: without provision for vacuum, for thermal expansion of heat-resistant metals or for a protecting atmosphere; a vacuum dilatometer for studying the thermal expansion of non-heat-resistant metals and the sintering of metal-ceramic specimens; and a vacuum dilatometer for investigating the dynamics of sintering of metal-ceramic specimens during rapid heating and cooling.

A high temperature recording dilatometer R. J. Beals and J. H. Lauchner (*Amer. Ceram. Soc. Bull.*, 1958, **37,** Nov., 486–488) In the instrument described a photovoltaic cell is partially shielded from a light source as the specimen dilates. The e.m.f. generated is compared with a standard and a dilation curve is automatically plotted as a function of specimen temperature (up to 1300°C).—A. G.

Measurement of cobalt and nickel vapour pressures N. Nesmeyanov and De Dyk Man (*Doklady AN*, 1958, **123,** (6), 1064–1067) The vapour pressures were measured by Langmuir's method (*Phys. Rev* 1914, **4,** 337, *J. Am. CS* 1940, **62,** 1382). The apparatus is described in detail in a previous publication (*Doklady AN*, 1957, **112,** 700). The data have been tabulated for temperatures from 1118–1270° for Co and for 1130–1252° for Ni.

The effect of Si, Cr and Mn on the equilibrium of carbon and oxygen in molten iron saturated with carbon. Equilibrium of carbon and oxygen in molten iron saturated with carbon. II S. Banya and S. Matoba (*Tetsu to Hagane*, 1958, **44,** June, 643–649) The effects of Si, Cr and Mn up to 5·2, 20 and 40%, respectively, were studied. Si decreased, and Mn and Cr increased, the concentrations of carbon and oxygen in molten iron; temperature-independent functions express the changes. The interaction parameter of O and C in molten iron is also expressed (15 references).—K. E. J.

The carbon equilibrium with liquid alloys of Fe, Mn, Si and C M. S. Petrushevskii and P. V. Gel'd (*Zhur. Priklad. Khim.*, 1959, **32,** (1), 86–95) On the strength of investigations of the C solubility in binary alloys Fe, Si and Mn–Si at 1460° it was established that with an increase in the Si concentration the activity coefficient of C increases, the increase being more pronounced in the first system than in the second. The C solubility in Fe–Mn–Si showed that as a rule the C activity coefficient increases with the Si content.

Thermal stresses in reinforced concrete structures K. Jäger (*Österreich Ing. Z.*, 1958, **1,** April, 184–191; May, 219–224) Mathematical. Temperature changes in statically undetermined framed structures cause internal stress owing to the partial or total prevention of changes in length. The conventional calculation of these strains leads – as the author shows – to a substantial overestimation of the additional forces. The author presents a method of calculation of the true strain and gives a number of numerical examples.—T. G.

Super high pressures L. F. Vereshchagin (*Nauka i Zhizn*, 1957, Dec., 11) Properties of materials including steel and cast iron under hydrostatic pressures of 20 000–30 000 atm are discussed. The possibility of operating rolling mills under these conditions is considered. The ductility would be greatly increased and the strength doubled. The development of power compressors for such purposes is reviewed, at present machines with outputs of 60 l/h at 10 000 atm. and 2000 l/h at 2000–2500 atm have been constructed.—E. S.

High-temperature metallurgy today L. P. Jahnke and R. G. Frank (*Met. Prog.*, 1958, **74,** Nov., 77–82) The present position of high

temperature metallurgy is surveyed, and the most promising fields for development are considered. The mechanism of methods of increasing metal-strength by blocking the movement of dislocations is examined. The martensitic tool steels have a unique strength-to-weight ratio in the 400 to 1 000°F range, but semi-austenitic steels have a balance of properties including corrosion resistance which allow wide application in this region.—D.L.C.P.

Effect of composition on the elevated temperature properties of ductile iron R. D. Schelling and J. T. Eash (*Blast Furn. Steel Plant.*, 1958, **46**, July, 746–748) The effects of variation in the P, Cu and Mo contents and heat treatment on the creep resistance of ferritic and pearlitic ductile iron at 800°C has been studied. The tensile strength, stress-rupture and creep properties of a Ni–Cu ductile iron at temperatures up to 1 000°F and of a 20–35%Ni austenitic ductile iron at temperatures up to 1 400°F are also discussed.—B. G. B.

A survey of work on the high temperature properties of austenitic steels in cyclic temperature changes L. Ya. Liberman (*Metallov. Obra. Met.*, 1958, (2), 38–49) A review, mainly of work published in the US.

Investigation of the resistance to cold of some steel compositions A. P. Sanina and M. M. Tomofeev (*Metallov. Obra. Met.*, 1958, (8), 57–58) Alloying elements Mn, Si and Cr are most suitable for steels in use in northern cold regions. P content should be low. The recommended steels contain: 0·1–0·15%C, 0·5–0·7%Si, 0·7–1·0%Mn, 0·5–0·68%Cr, 0·03%P and 0·12–0·17%C, 0·4–0·6%Si, 1·0–2·1%Mn and 0·015%P respectively.—L. H.

Mechanism of the carbon diffusion peak in FCC iron-nickel alloys Wu Tzu-Liang and Wang Chi-Min (*Scientia Sin.*, 1958, **7**, Nov., 1029–1053; *Acta Phys. Sin.*, 1958, **14**, (4), 354–368) [In English] The peak arises from preferential rotation of the axes of carbon pairs in the specimen and an equation is derived on this hypothesis relating peak height and carbon concentration.

Determination of the parameters of diffusion of iron and chromium in some of their alloys L. I. Ivanov and N. P. Ivanchev (*Izvest. Akad. Nauk, Otdel. Tekhn.*, 1958, (8), 15–18) The relationship of coefficient of diffusion to temperature is investigated for three low-C Fe–Cr alloys containing 26, 49 and 82% Cr respectively (12 references).

Solubility of nitrogen in liquid iron and in iron-silicon melts V. P. Fedotov and A. M. Samarin (*Doklady AN*, 1958, **122**, (4), 597–599) Experiments at 1 580°C in various environments on the solubility of nitrogen in Fe–Si melts lead to the following conclusions: (1) at a content of oxygen of 0·003% the amount of dissolved nitrogen in iron is 0·055%, with an increase of oxygen the amount of dissolved nitrogen decreases; (2) with increase of temperature the amount of dissolved nitrogen increases; (3) the influence of pressure is in conformity with the law of Sieverts; (4) the influence of silicon: with increase of Si from zero to 15% the amount of dissolved nitrogen decreases; above 15% it increases; (5) annealing reduces considerably the amount of nitrogen dissolved in iron.—S. I. T.

Considerations regarding steels containing nitrogen S. Bercu, A. Kathrein, and R. Fishgold (*Studii si Cercetari de Metalurgia*, 1958, (3), 385–396) [In Rumanian] Nitrogen is an alloy element which can replace nickel in austenitic heat-and-corrosion-resistant steels. It stabilizes the austenitic structure at normal temperatures, reduces the critical rate of tempering by inhibiting martensite transformation and it also inhibits intercrystalline corrosion in Cr–Ni and Cr–Mn steels and reduces grain size in Cr steels.

Application of nitrogen solubility data to alloy steelmaking F. C. Langenberg and M. J. Day (*AIMME Elect. Furn. Steel Conf. Proc.*, 1957, 7–16) Solubility data for various alloy contents were assembled from the literature and plotted and used to derive activities and solubility indices. The use of these values to predict solubilities is illustrated and applied to recoveries from scrap.

Some notes on the nitrogen-porosity relations in chromium–nickel–manganese steels G. R. Adams, W. O. Binder, and J. Thompson (*AIMME Elect. Furn. Steel Conf. Proc.*, 1957, 17–20) Nitrogen is a strong austenite former and can be used to minimize Ni content, but may also lead to porosity development. Compositions leading to gassy ingots and sections of these ingots are given. Both Mn and Ni raise the amount of N_2 that may be present, cooling rate is relatively unimportant.

Effect of environment on the rate of hydrogen removal from steel R. M. Hudson, W. G. Norris, and G. L. Stragand (*Ind. Eng. Chem.*, 1959, **51**, Mar., 319–324) Low-carbon sheet was electrolytically charged with H_2 and then degassed in special glass apparatus for 16 h at 160°C. Tests in various aqueous solutions of oxidizing agents were carried out and it was found that this often hindered H_2 removal. Work in non-aqueous environments is also reported.

Some problems of the theory of alloying special casting alloys with high contents of alloying elements Yu. A. Nekhendzi (*Lit. Proizv.*, 1958, (10), 23–29) The alloying of, and development and choice of a composition for such casting alloys, and their physical properties are in many cases determined not only by the influence of the alloying elements but to a large extent by the technological conditions under which the castings and the test pieces are prepared; amongst such factors are the cooling rate, duration of solidification, the extent to which the castings are fed and the shrinkage. In this article a review is given of the results of research carried out on γ-alloys with a fixed content of C (0·12 and 0·35%) and varying nickel contents (0–80%), i.e. typical acid- and heat-resisting Fe- and Ni-base alloys. Additions of 15 and 20%Cr were made, and also of the following elements (up to 10% for Fe-base and 20% for Ni-base alloys): Mo, W, Nb, V, Ti, Al, i.e. elements which simultaneously form hardening carbides, carbonitrides and intermetallic phases as well as ferrite. Further experiments were made with Mn, Cu, Co and N. In addition to the factors outlined above, a study was made of mechanical testing techniques and the varying results obtained from test-pieces taken from different parts of a casting. The scope of the article is extremely wide, since it summarizes a series of detailed investigations carried out on specialized aspects of the problems outlined.—M. T.

The influence of carbon on the properties of 18–4–2 type high-speed steel N. Yamanaka, K. Kusaka, and M. Kitahara (*Tetsu to Hagane*, 1958, **44**, Aug., 886–891) The effects of carbon were investigated from measurements of critical temperatures, M_s point, quenched and tempered hardness, retained austenite, dimensional changes, toughness and mechanical properties at high temperatures.—K. E. J.

Alloy stands up to heat (*Steel*, 1959, **144**, Jan. 12, 84–85) Properties of a new heat-resistant Cr–Mn–Ni steel are listed together with recommended methods of heat treatment, machining, forging and welding. The steel is known as Armco–22–4–9.—A. G.

Tellurium in steel Ya. E. Gol'dshtein (*Stal'*, 1959, (2), 156–159) Te greatly refines secondary grain size and increases resistance to grain growth during heating up to 1 150°C and also reduces temperability. Micro-alloying with Te also reduces carburizing intensity during case-carburizing and makes it possible to avoid supersaturation of the surface layers and the associated brittleness; it is recommended for a wide range of structural steels to obtain fine-grained structure, to lower susceptibility to overheating and to increase hardenability of entire parts or of their working surfaces while lowering temperability and susceptibility to hardening crack formation.—R. S.

Stability of the structure and properties of heat-resisting chromium steels A. V. Merlina and A. M. Borzdyka (*Stal'*, 1959, (2), 160–165) The 3%, 5–6% and 12%Cr steels with Mo, W, V and Nb are covered and the carbide phases are investigated. Creep curves are given for 3%Cr, Mo, W, V and Nb steel at 550°C under 12 kg/mm² load. The carbide phase is very stable with temperature, the stability of the structure is increased by finely divided uniformly dispersed V carbide especially with Nb carbide. The 5%Cr steels are less stable and contain $(Cr, Fe, W, Mo)_7C_3$ which is unstable especially above 500°C. In 12%Cr steels $(Cr, Fe, W, Mo)_{23}C_6$ is present. The most stable structure is that of 0·2%C, 0·46%Mn, 0·22%Si 12·7%Cr, 0·40%Mo, 0·73%W, 0·4%V and 0·27%Nb, all Nb being carbide with a corresponding increase in free Cr. This prevents impoverishment of the solid solutions in Cr, W and Mo.—R. S.

Research into new types of low-alloy steel for welded structures T. M. Slutskaya and V. G. Gordonny (*Avtom. Svarka*, 1958, **11**, (9), 3–12) Many existing types of low-alloy steels either lack sufficient strength or have poor weldability or both, and are therefore unsuitable as constructional steels in welded structures employing plates >70 mm thick, while such steels often require complicated post-weld heat treatment. Research was carried out with the aim of developing steels which would overcome these defects. Mo was not used for alloying, firstly because it may promote brittleness, and secondly on grounds of expense; on the last ground the use of Ni was restricted to small quantities (≤1%). Small quantities only of V (≤0·15%) were also used for alloying, in addition to Mn (≤2·0%) and Cr (≤1%). The C content was restricted to 0·15–0·18%. Three satisfactory compositions for steels were obtained from the experiments with the following properties: yield-point 35–40 kg/mm²; u.t.s. 50–50 kg/mm², elongation 28–35%; reduction in area, 70–73%; impact strength 17–30 kg m/cm².—M. T.

METALLOGRAPHY

Studies on Kish graphite F. Roll (*Arch. Eisenhüt.*, 1959, **30**, Feb., 91–94) The chemical composition, structure, and inclusions were determined on Kish particles from haematite, foundry pig iron, and ferrosilicon with 10%Si. The effect on structure of thermal etching in oxygen or carbon dioxide was also studied.

Contributions to the study of the influence of the manufacturing process on the content and nature of non-metallic inclusions in steel S. Dascălu (*Rev. Mét.* (*Bucarest*), 1958, **3**, (3), 87–100) The amount and types of inclusions found in steel are examined in relation to the manufacturing technique employed. The direct influence of factors influencing inclusion content, such as speed of decarburization and duration of boil, and indirect influences such as slag properties are discussed, and the importance of correct deoxiding practice is emphasized.

Election microscopical observation of A-type non-metallic inclusions in ball-bearing steel H. Suyama (*Tetsu to Hagane*, 1958, **44**, Sept., 1101–1103).—K.E.J.

Study of leaded free-cutting steels VII. Study of the behaviour of lead inclusions in leaded tough and hard steels T. Araki (*Tetsu to Hagane*, 1958, **44**, Sept., 1197–1199).K.E.J.

Study on carbides in high speed steels. II. Behaviour of the carbides and heat-treatment in high-W and Mo high-speed steels S. Kimura (*Tetsu to Hagane*, 1958, **44**, Sept., 1085–1086) The percentages and compositions of carbides and matrices are given for various types of heat-treatment.—K.E.J.

Study on carbides in commercial special steels by electrolytic isolation. IX. On carbides in Mo, W, Mo and Co high-speed steels T. Sato (*Tetsu to Hagane*, 1958, **44**, Sept., 1089–1091) The chemical compositions of carbides and ferrites, weight % of carbide, and the compositions of carbides as revealed by X-ray patterns are given.—K.E.J.

The needle-like non-metallic inclusions in steel. The behaviour and constituents of the inclusions during cooling K. Matsubara (*Tetsu to Hagane*, 1958, **44**, Sept., 1038–1039) The occurrence of inclusions in Ni–Cr and carbon steels is examined, and compared with the chemical analyses and Mn/S ratios.—K.E.J.

Carbide reactions in 13% chromium steel M. Tanino (*Tetsu to Hagane*, 1958, **44**, Sept., 1127–1128) Reactions involving carbides of the type $M_{23}C_6$ and M_7C_3 are studied with the aid of photomicrographs.—K.E.J.

Secondary recrystallization in silicon iron J. E. May and D. Turnbull (*Trans. Met. Soc., AIME*, 1958, **212**, Dec., 769–781) The effects of impurities on the (110)[001] secondary

recrystallization texture were studied by making specific impurity additions to high-purity Fe–Si. The impurities formed a dispersed second phase. A function of the inclusions is to inhibit normal grain growth and thus maintain the driving energy for secondary recrystallization (30 refs.).—T.G.

Sinking under bosses on thin plates J. W. Dews and A. G. Fuller (*BCIRA J. Res. Dev.*, 1958, **7,** Dec., 392–400) Laboratory observations indicate that unsoundness increases with the number of eutectic cells. This is governed by the treatment the metal has received and is often independent of composition. Investigations in a light castings foundry have shown that the number of eutectic cells growing varies greatly during the day.—A.G.

Secondary and tertiary recrystallisation of mild iron hardened by rolling and annealed in hydrogen P. Coulomb and P. Lacombe (*Compt. Rend.*, 1959, **248,** Feb. 16, 964–966) After annealing in H_2, mild iron exhibits a secondary texture notable for the absence of (100) crystals parallel to the plane of the sheet. This is generally replaced by a tertiary texture o (110)[001] coarse grains.—A.G.

Texture of cold-rolled and recrystallised crystals of silicon iron J. L. Walter and W. R. Hibbard jun. (*Trans. Met. Soc., AIME*, 1958, **212,** Dec., 731–737) Silicon iron crystals rolled in a direction nearly parallel to the [001] direction were examined to determine the relationship between the initial orientation, the cold-rolled texture and the recrystallized texture. The results are presented in many pole figures and discussed in detail.—T.G.

Electrical resistance effects associated with the allotropic transformation in high purity iron K. Shimura, E. Eichen, and J. W. Spretnak (*WADC Tech. Rep.* 57–738, *ASTIA Document No. AD* 142207; *PB* 151205–200, 1958, Jan. 1, pp.64) Measurements were made in a vacuum on wires 25 mil dia. and ½ cm long. At the α- to γ-change a decrease in resistance of about 1·3% was observed, but on cooling no sudden change occurred. On re-cycling total resistance fell steadily, apparently due to change of dimensions, the dia. increasing. Study of the kineties by indirect heating gave inconsistent results. Disadvantages of the method are pointed out.

A contribution to austenite formation in unalloyed and low-alloy subeutectoid steels E. Schmidtmann and H. Brandis (*Arch Eisenhüt.*, 1959, **30,** Feb., 83–89) The isothermal α-γ-transformation of unalloyed and low-alloy steels has been investigated. Normalized polished samples of the steels CK15, CK35, CK60, 24CrMo5, 36CrNiMo4, and a steel with 0·8%Cr and 3·5%Ni were heated to temperatures above Ac_1 kept at these temperatures for varying periods, and quenched in water. The residual austenite and martensite contents were determined planimetrically in the undercooled specimens; the Vickers hardness was also measured. The activation energies of austenite formation were determined.—L.J.L.

Studies on ultra-high-strength steel. I. Transformation behaviour and tempering characteristics of 0·4% C Si–Mn Cr Mo steel K. Tasaka and T. Okada (*Sumi. Met.*, 1958, **10,** Oct., 224–230) [In Japanese] The data include isothermal and continuous-cooling transformation diagrams, tempering and softening behaviour, and information as to the '500°F embrittlement'. This steel is tougher than ordinary low-alloy constructional steels at tensile strengths of about 200 kg/mm² (17 refs).—K.E.J.

Effect of interstitial carbon plus nitrogen and precipitation reactions on the properties of austenitic Cr Mn C N steels C. M. Hsiao and E. J. Dulis (*Trans. ASM*, 1958, **52,** *preprint* 128, pp.40) Effect on mechanical properties at ordinary and elevated temperatures were studied. In the solution-treated condition solid solutions can be maintained at room temp. but heating, in heat treatment or in service, enables precipitation to occur. C and N increase tensile strength and the mechanism is considered. Effects of precipitation in creep-rupture tests are discussed.

A survey of views and researches on the morphology of the transformation in 18/8 and 16/13 Cr–Ni steels I. Hrivňák (*Zvár. Sbornik*, 1958, **7,** (3), 362–387) [In Slovak] A survey of the literature is made, and a description is given of electron micrographic work carried out by the author on the processes of precipitation and the formation of sigma phase.—F.F.

Research into cooling rates after welding and their application to the anisothermal breakdown of austenite A. Havalda (*Zvár. Sbornik*, 1957, **6,** (2), 239–261) Thermal processes during unshielded arc welding are studied and factors affecting the extent of the heat-affected zone are examined. Cooling diagrams are presented and thermolcycles for restricting the brittle zones are chosen. Two types of steel are studied but it is regarded as important to extend the method to others.—M.T.

Constitutional diagrams for metals (*NBS Research Highlights, Annual Report*, 1958, Dec., Misc. Publ. 226, 52) Work on 431 stainless steel is referred to. **Commercially important alloys** New phases were observed in high-temperature Fe–Mo–Ni and similar alloys. **High-temperature metals** (52–53) Steels for use in aircraft are being developed and work on 17–7 PH steels is noted.

Investigations of the stable and metastable equilibrium of iron carbon alloys T. Heumann and J. Grosse-Wördemann (*Arch. Eisenhüt.*, 1959, **30,** Jan., 35–39) In view of discrepancies in published results of eutectic temperatures and the solubility of C in γ-solid solutions in stable and metastable equilibrium in the Fe–C system, investigations were carried out on pure Fe–C alloys containing 0·02–4·52%C and pure Fe_3C powder. Thermal and radiographic analysis and microscopical examination were used. Temperatures of eutectic solidification were 1152°C for the γ-iron-graphite eutectic and 1144°C for the γ-iron-cementite eutectic; cementite is unstable over the whole of the temperature range investigated.

Structural transformations in cast iron saturated with magnesium in the zone of eutectic temperatures P. I. Stepin (*Lit. Proizv.*, 1958, (11), 24–27) Structural transformations and the mechanism of the graphite formation in cast iron treated with Mg are not yet fully explained. Existing publications do not give any guidance which could be utilized in production. The following investigations were performed by the author. Into a cast iron (or steel) cylindrical specimen (30 mm dia., 80 mm height) a pellet of Mg was embedded in the top, the whole was put into a steel container tightly closed and heated to various temperatures. Five types of cast iron and one of steel were tested. Photomicrographs were taken; the depth of diffusion of Mg into the solid, liquid, and mixed phases of iron was determined. It was found that the process of diffusion is greatly enhanced by pressure. The influence of Mg on graphite formation was thoroughly investigated; it was found that lamellar and globular graphite react in a different way. The replacement of Mg by Al did not alter the general trend of the processes. Hope is expressed that this research throws some new light on the process of graphite formation and can be used as a basis for further research.—S.S.

Factors controlling the graphitization of high-carbon steel at subcritical temperature. I. (Study on the graphitization of high-carbon steel – I) N. Yamanaka and K. Kusaka (*Tetsu to Hagane*, 1958, **44,** Oct., 1180–1185) The steel containing about 1·1%C and killed with Al and Si was studied for the factors which control graphitization. It was found that the rate of cementite dissociation was a maximum at about 650°C and was higher the higher the martensite content in quenched specimens. Furnace-cooled or air-cooled or isothermally transformed samples showed less graphitization. Cold-working accelerated the formation of graphite nuclei.—T.G.

Study of graphitic steel. V. Heat-treatment of graphitic steel of the Fe-C-Si system. I T. Sato and S. Toya (*Nippon Kinzoku*, 1957, **21,** Nov., 648–651) In fully pre-graphitized steel containing 1·5%C and 1·5%Si, the period for resolution of graphite into austenite up to saturation at 850°C is about 20 min; in partially pre-graphitized steel, about 10 min. The quenching hardness varies with the distribution of graphite particles. Hardenability increases with Si content but decreases with C content.—K.E.J.

Isothermal transformation of austenite M. Hillert (*Varm. Bergsmann. Ann.*, 1958, 29–62) Proeutectoid and eutectoid precipitation and the nature of bainite are discussed, the microscopic structure of pearlite and porous cementite and abnormal structure are examined in relation to the isothermal transformation of austenite (16 references).

Anisometer for determining the influence of stress and deformation of austenite decay P. V. Novichkov (*Zavods. Lab.*, 1958, (12), 1510–1511) A new apparatus is described consisting of a base-plate carrying a movable electromagnet, a special device for stressing specimens and a container for liquid nitrogen for the cooling of isothermal heaters. This special construction is very sensitive and specially suitable for measuring very small changes of the ferromagnetic phase.

The kinetics of the isothermal transformation of austenite in carbon steels under induction heating I. N. Kidin and Yu. A Bashnin (*Metallov. Obra. Met.*, 1958, (7), 10–15) Four types of steel (0·37–0·93%C, 0·4–0·66%Mn, 0·25–0·31%Si, 0·016–0·042%P, 0·018–0·021% S) were investigated under induction heating with immediate immersion of the specimens into an isothermal molten tin bath. The austenite in these steels when induction heated is less resistant than when heated by the usual methods because of carbon non-homogeneity and grain refinement. The kinetics of austenite decay with induction heating are similar to those in the pearlite temperature range in ordinary heating.—L.B.

Characterizing steels on the basis of the kinetics of austenite formation R. Mitsche and A. Legat (*Berg. Hütten. Monatsh.*, 1959, **104,** Jan., 8–11) The importance of austenitic grain size in assessing steel properties is emphasized, and the limited value of the McQuaid–Ehn test is pointed out. The effect of heating conditions on austenitic grain growth is examined critically.

A contribution to the problem of the transformation behaviour of steel in hardening layers H. Schenck, E. Schmidtmann, and P. Schmithals (*Arch. Eisenhüt.*, 1959, **30,** March, 153–160) The object of the investigations was to determine whether the transformation behaviour of steel in hardening layers could be confirmed by comparative tests on 'model steel' alloys. Specimens of steel with 0·15%C and 1·25%Mn were carbonized for 6 h at 870°C, for 10 h at 930°C, or for 20 h at 950°C, normalized, austenitized at 930°C, and then transformed isothermally at temperatures in the pearlite and intermediate ranges.—L.J.L.

The change in the kinetics of the martensite transformation under the influence of irradiation A. I. Zakharov and O. P. Maksimova (*Izvest. Akad. Nauk, Otdel. Tekhn*, 1958, (7), 3–9) The results are described of the preliminary neutron irradiation of steel specimens on the kinetics of the isothermal martensite transformation at various temperatures. The steel, N22G3, contained 0·02%C, 22·4%Ni and 3·48%Mn.

Producing martensite by impact H. O. McIntire and G. K. Manning (*Metal Progress*, 1958, **74,** Nov., 94) An examination of chipped hammers is reported. It was found that martensite can be formed by sharp impact, and in chipped hammers the brittleness makes further spalling likely.—D.L.C.F.

On the nature of the X-phase F. N. Tavadze and I. A. Bairamashvili (*Lit. Proizv.*, 1958, (11), 18–20) Grey cast iron differs from ordinary carbon steel, within the range of temperatures 750–850°C, in its greater chemical heat stability. This is explained not only by a greater thickness of oxide films on grey cast iron but also to the fact that oxidation takes place in the whole volume of the iron; a new structural phase, the so-called X-phase, appears. Besides the X-phase another X′-phase has been found, which differs from X-phase by its greater density and hardness. The author discusses various processes which can result in formation of these phases. The content of X′-phase increases with the content of Mn. The author comes to the conclusion that the nature of the X-phase has not yet been explained. The X′-phase seems to be a very complex compound, containing solid solutions.

The presence of spheroidal graphite contributes to the formation of the X′-phase, at the same time the X-phase is practically absent.

The interatomic interaction in iron-chromium alloys A. G. Lesnik (*Doklady AN*, 1958, **122**, (3), 385–388) It is shown here that the introduction of the hypothesis of the formation of polar state of atoms in alloys allows us to understand features of the breakdown of alloys with the formation of an intermetallic compound of variable composition of σ-phase type. Introducing three postulates, a complex mathematical treatment leads to the formulation of the free energy of mixing, the diagram of state of the Fe–Cr system and other functions.—S. I. T.

Phase constitution of chromium-nickel austenitic steels containing titanium V. I. Prosvirin (*Metallov. Obra. Met.*, 1958, (10), 2–5) Steels containing 0·06–0·10%C, 13·4–14·9%Cr, 15·6–25·3%Ni, and 0·68–2·66%Ti were examined. An increase of the hardening temperature from 900 to 1 250° (1 h exposure) does not bring about complete solution of the secondary phase. The quantity of the secondary phase after hardening is greater in steels with less Ti. Ageing after quenching from 1 250° causes appreciable precipitation of secondary phases the degree of which varies from steel to steel and also with temperature.

Investigation of the Ti-rich Ti-Fe-Mn alloy system – On the solid equilibrium relation in the Ti-Fe-Mn system Y. Murakami and T. Enjyô (*Nippon Kinzoku*, 1958, **22**, June, 328–332) Investigation by X-ray analysis and other means is said to reveal a large range of ternary solid solution of Ti ($FeMn)_2$. General equilibrium relationships in the system are summarized.—A. G.

CORROSION

Study of pitting corrosion of high-alloy austenitic chromium-nickel steels and ferritic chromium steels in aqueous halide-bearing solutions G. Pier and W. Schwenk (*Werks. Korr.*, 1959, **10**, Feb., 78–81) Pitting occuring in these steels when immersed in solutions which contain halide ions and an oxidizing agent is caused by the action of an active–passive cell. At the active anode spots, metal ions enter the solution whereas at the passive cathode areas the electrolyte is reduced. A certain halogen concentration is necessary for the formation and upkeep of the active, point-like anode spots. The susceptibility of steels to pitting can easily be tested by immersion in a 0·5% $K_3Fe(CN)_6$ solution.—T. G.

Studies of stress-corrosion cracking of austenitic stainless steel H. L. Logan (*Welding J.*, 1958, **37**, Oct., 463–467) The stress-corrosion cracking of austenitic stainless steel type 304 was investigated in boiling 0·5N NaCl, 0·1N $NaNO_2$ solution. It is concluded from the results that stress corrosion is electrochemical in its inception and to some extent in its propagation. The mechanism is discussed.

Effect of cathodic and anodic polarization on the rate of stress corrosion of austenitic stainless steel V. V. Romanov and V. V. Dobrolyubov (*Metallov. Obra. Met.*, 1958, (7), 19–21) A steel with 0·01%C, 19·98%Cr, 0·95%Ni and 0·06%Ti with tensile strength 67kg/mm² and 61% elongation, cut in the direction of rolling, was surface polished with emery paper, degreased, and exposed to corrosion in 92% $MgCl_2$ at b.p. (153°C) under uniaxial tension (30 kg/mm²). The surface was polarized with d.c. and time to failure was observed. The fractures were sectioned and examined. Cathodic and anodic polarization curves are plotted and their relation to corrosion cracking is explained.

Fretting corrosion of cast iron K. H. R. Wright (*Institution of Mechanical Engineers, Conference on Lubrication and Wear, London*, 1957, 628–634) Statistical treatment of a series of experiments on 12 cast-irons under six conditions of lubrication and dry is carried out. The dry conditions correlate wear with hardness and an expression is advanced for the relationship. With oil or grease the correlation is less marked but approximates to an inverse first-power expression. Extreme pressure additives and MoS_2 in oils were found to have ttle or no effect on fretting. High P content, (0·8–1%) is advantageous on account of its hardening effect. **Experimental investigation of some processes involved in fretting corrosion** J. S. Halliday (640–646) Attempts to isolate the mechanisms are described. Mild steel and non-ferrous metals were used. Fretting is shown to break down the oxide films and to form intermetallic welds, and then to give rise to debris which rolls or slides. In oil, welding continues and while corrosion is insignificant, no lubrication is achieved. **Cavitation of metal surfaces in contact with lubricants** R. W. Wilson and R. Graham (707–712) Non-ferrous specimens immersed in pure organic liquids were examined by an ultrasonic oscillator process.

Corrosion and metallographic study of stainless steels using potentiostat techniques Vladimír Čihal and Milan Pražák (*JISI*, 1959, **193**, Dec., 360–367) [This issue].

The fatigue fracture under corrosion of reciprocating saw connecting rods J. Salokangas (*Acta Polytechnica Scand., Mechanical Engineering Series No. 4*, 1958, pp.23) Corrosive conditions in Finnish sawmills are discussed, and the results of a statistical study of the influence of corrosion on the fatigue fracture of reciprocating saw connecting rods are given. Incipient fatigue fracture was investigated ultrasonically.

Corrosion of iron and zinc in N H_2SO_4 L. I. Antronov and A. T. Petrenko (*Zhurn. Priklad. Khim.*, 1958, **31**, (12), 1849–1856) For zinc, adsorption inhibitors are the cathode-active substances. The anode-active substances on the contrary increase corrosion. The most efficient inhibitors for iron and zinc in N H_2SO_4 are the silicon organic compounds, inhibiting the dissolving of iron in these conditions by a factor of ~20 in concentrations of 0·1% and of zinc by 2·5 to 8 times. for concentrations between 0·1 and 0·2%.

Investigation of the effect of boiling concentrated sulphuric acid on the corrosion of iron Lo Ben-Yun and Ko Sen-Chen (*Acta Met. Sin.*, 1958, **3**, (3), 231–233) (No summary.) Effects of C, Si, Mn and P in 72% and 95% H_2SO_4 are given.

The effect of chlorine dilution by nitrogen on metal corrosion at high temperatures Kh. L. Tseitlin and V. A. Strunkin (*Zhurn. Priklad. Khim.*, 1958, **31**, (12), 1843–1849. Considerable dilution of chlorine by commercial nitrogen rapidly lowers the rate of corrosion of Al, Fe and its alloys, and Ti (to a smaller extent), Cu (above 230°), Ni (above 600°), Pb (above 250°) and, except in the case of Al, increases relatively little the critical temperature of the strength of metals. Purification of the commercial N_2 from its oxygen content increases the reactivity of the gas current containing chlorine. Explanations are suggested for the inhibition of corrosion by the dilution of the chlorine.

The effect of surface active agents on the formation of boiler scale G. H. Ireland (*Corros. Prev.*, 1958, **5**, Oct., 57–60) The mechanism of scale formation, particularly the calcite and anhydrite scales formed on heating and cooling surfaces of industrial plant, is discussed, and the use of a surface active agent, Belloid FW, is described, which has been specially developed for water treatment. Its use in boilers and other systems is described.

Causes and prevention of surface fissures on hot-worked steel products. II T. Ohtake, K. Ishizaki, and N. Eguchi (*Nippon Kinzoku*, 1957, **21**, Nov., 640–644) Oxidation of commercial steels causes a progressive surface enrichment of tramp elements (Cu, Sn, As) until a non-ferrous liquid phase may appear. This never penetrates deeply into the matrix. The scaling loss needed to produce this agrees exactly with that to cause surface fissures. The fissures are thus a type of stress-corrosion crack associated with this liquid formation.

Electron diffraction studies on the high temperature oxidation of Fe-Al alloys: On the effects of heat-treatment T. Nakayama (*Nippon Kinzoku*, 1958, **22**, June, 332–335) When various Fe-Al alloys are heated in air below 700°C mixed crystals of γ-Al_2O_3 and iron oxides (mainly α-Fe_2O_3) are formed on the surface. The mechanism of formation of such films is discussed.—A. G.

An accelerated corrosion test chamber W. Hess (*Corros. Prev.*, 1958, **5**, April, 47–51) The equipment described by the author, and developed in the Swiss PTT chemical laboratory for accelerated corrosion tests, has features which obviate errors resulting from the normal rapid examination. Jets of liquid normally used are replaced by aerosols to give constant dispersion; air circulation is substantially reduced, and inert or other special atmospheres can easily be introduced with the aerosols.

Corrosion studies XXII. Activation energy of the passivation of iron in sulphuric acid K. Smrček, I. Sekerka, and J. Vorliček (*Chem. Listy*, 1958, **52**, (12), 2212–2215).

Influence of metallurgical variables on resistance of steels to sulphide corrosion cracking J. P. Fraser and G. G. Eldredge (*Corrosion*, 1958, **14**, Nov., 524t–530t) A statistical study is reported on the sulphide corrosion cracking of steel as a function of chemical composition, mechanical properties and heat treatment. Resistance to cracking is increased most rapidly by increases in ductility and C content, and decreased by increased hardness, strength and Mn and Mo content. Resistance to cracking of N–80 steel is markedly improved by tempering for ½ h at 1 100°F.—D. L. C. P.

Contribution to the study of corrosion resistance of SG cast iron I. Cornea (*Studii si Cercetari de Metalurgie*, 1956, (1), 37–48) [In Rumanian]. In an HCl medium the corrosion resistance of SG cast iron is up to double that of grey cast iron of the same chemical composition. Ferritic irons are more resistant than pearlitic or pearlitic–ferritic. Irons with smaller Si content (2·6%) are more resistant than those with 4%Si. This is apparently due to a reduction in the ratio between cathodic and anodic surfaces in SG cast irons compared to grey irons and it is specially noticeable in corrosion with hydrogen depolarization. This deduction is therefore valid for HCl corrosion.

Evaluation of stress corrosion effects H. P. George (*MET* 365–574; *PB* 131783–800, 1956, Dec., 459–475) The nature of stress corrosion and methods for its quantitative evaluation are discussed. The investigations of Graf and Robertson on the stress corrosion of homogeneous alloys are described, and their findings summarized (15 refs).

Gases in steel: Stress-corrosion cracking of hardenable sheet steels B. F. Brown (*Rept. NRL Progress*, 1958, *PB* 151333–125, Dec., 35) 422 stainless steel stressed in tension with a small hole as stress raiser was exposed to 1% acetic acid in water saturated with NaCl and H_2S. Steel tempered at 1075°F cracked extensively before shear fracture, but at 925°F this was scarecely measurable. This latter treatment gave brittle fracture rather than stress-corrosion failure. As usually conducted the test measures a combination of these processes.

The problem of the rupture of steels in the presence of Lacq gas P. Bastien (*Arts Manuf.*, 1959, (Special No.), Jan., 59–60) The effect of natural gas containing H_2S and moisture is considered. A classification of steels on hydrogen embrittlement susceptibility was developed.

Problems of the exploitation of the Lacq deposits from the point of view of corrosion L. Cauchois (*Arts Manuf.*, 1959, Jan., 61–64) Steel pipe requirements are considered, also the valves and casing.

Oxidation of experimental alloys J. C. Richmond and H. R. Thornton (*WADC Tech. Rep.* 58–164 Part I, *ASTIA Document No.* 155688; *PB* 151264–150, 1958, June, pp.49) High temperature alloys were examined including 316 stainless steel and an Fe–Cr–Al alloy and 8 non-ferrous compositions.

Oxidation of three iron–nickel alloys and iron at 800°C S. W. Kennedy, L. D. Calvert, and M. Cohen (*Trans. Met. Soc., AIME*, 1959, **215**, Feb., 64–72) A high-temperature X-ray diffraction method was used to investigate the scaling of three Fe–Ni alloys at 800°C in O_2 at atmospheric pressure, using a Norelco Geiger-counter diffractometer; other techniques were also used, and results obtained by the various methods were essentially in agreement. In the 25%Ni alloy a spinel and Fe_2O_3 was formed

while the 75 and 84%Ni alloys formed a 3-layer scale consisting of porous NiO next to the metal, followed by a spinel layer with α–Fe_2O_3 on the outside.

The decomposition of wustite in the layer of scale on iron specimens W. A. Fischer and A. Hoffmann (*Archiv. Eisenh.*, 1959, **30,** Jan., 15–22) An examination of the decompostion of wustite below 570°C in air in scale formed by the oxidation of specimens of high-purity iron, Armco iron and 0·1%C unalloyed steel at 750–1050°C showed that the decomposition structure is influenced mainly by the temperature of breakdown and not significantly by the temperature of oxidation. The structures obtained are examined and illustrated.

DSIR corrosion of metals group, National Chemical Laboratory, Teddington F. Wormwell (*Corros. Techn.*, 1959, **6,** Jan., 5–9) The evolution and activities of the National Chemical Laboratory are reviewed. Recent work has included studies of inhibitors, immersed corrosion at higher temperatures, and bacterial corrosion.—A. G.

Correlate corrosion testing methods R. V. Jelinek (*Chem. Eng.*, 1959, **66,** Jan. 26, 105–110) A general review of methods of corrosion testing and their significance and their relation to actual service endurance is given (42 refs).

The effect of boiler water additions on the corrosion rate of steel at 600°F M. C. Bloom and W. A. Fraser (*Rept. NRL Progress*, 1959, *PB* 151334–125, Jan., 34–35) Hydrogen effusion tests were made in 40%NaOH solution compared with pure water. The peak rate was 10 times greater with the former and increased suddenly after 20–50 h. The rate in water continued to fall up to 2 years.

Tube cameras for investigating corrosion problems A. G. Arend (*Corros. Prev.*, 1958, **5,** Dec., 53–55) A cine camera is described that automatically photographs the interior of bores or tubes, etc., for surface defects such as are caused by corrosion.—T. G.

New photographic method for investigating atmospheric corrosion of metals in the early stages I. L. Roikh (*Zhur. Fiz. Khim.*, 1957, **31,** (9), 1959–1963) Using the automatic photographic method described, corrosion of metals, as determined in terms of evolution of H_2O_2, is examined for the first few seconds from the commencement of oxidation.

Determining corrosion aggressiveness of the atmosphere N. D. Tomeshov, G. K. Berukshits, and A. A. Lokotilov (*Corros. Techn.*, 1958, **5,** Dec., 386–388) Apparatus with 15–20 copper and iron electrode pairs working at different humidities or in the open air is described. The work was done at the USSR Acad. Sci. and I.V. Stalin Steel Institute.

Device tells on corrosion (*Steel*, 1959, **144,** Jan. 12, 85) Two probes of the material being tested are used, one exposed to the corrosive medium and the other protected. Electronic measurement of the resistance ratio of the probes gives a rapid indication of corrosion.

Study on the corrosion of tin plate H. Asano (*Tetsu to Hagane*, 1958, **44,** Sept., 1074–1075) The effects of orange, peach and pear juice on canning materials are discussed.—K. E. J.

Corrosion test of stainless steels in an experimental oil distillation apparatus M. Hasegawa (*Tetsu to Hagane*, 1958, **44,** Sept., 1130–1132).

Underground corrosion investigation. I–II. (*Corros. Prev.*, 1958, **5,** Dec., 55–58; 1959, **6,** Jan., 52–54) The activities of the US National Bureau of Standards in investigating current and potential relations, electrochemical polarization and other electrical phenomena associated with the corrosion of underground structures are reviewed.—T. G.

Apparatus for examining the corrosion of stainless alloys in an aqueous medium at an elevated temperature E. Pouillard, H. Coriou, and M. Grall (*Mét. Corros. Ind.*, 1959, **34,** Jan., 20–35) A new method for examining the corrosion of stainless steels at high temperatures is described, in which 'microautoclaves' made of the specimens to be tested are used. Two types are used, depending on whether superficial or stress corrosions are to be investigated. Some examples are discussed.

Study of causes and effects of underground corrosion National Bureau of Standards (*J. Amer. Waterworks Assoc.*, 1958, **50,** Dec., 1581–1588) A brief history of NBS work during the last 45 years on underground pipe line corrosion with a review of work on cathodic protection since 1940.

Strain electrometry and corrosion. IV. Film properties and strain potential J. C. Giddings, A. G. Funk, C. J. Christensen, and H. Eyring (*J. Electrochem. Soc.*, 1959, **106,** Feb., 91–95) Iron and 5 non-ferrous electrodes were used and strain transients were measured. Their magnitude as a function of strain % is discussed. Effects of corrosion inhibitors and organic coatings were also examined. Theoretical interpretations are attempted.

Corrosion studies in dynamic aqueous systems at elevated temperature and pressure M. Krulfeld, M. C. Bloom, and R. E. Seebold (*NRL Report* 5152; *PB* 131775–050, 1958, June 26, pp.12) The H_2 effusion technique is applied to the measurement of corrosion rates at high temp. and pressure. Water flow at 1 ft/sec at 316°C and 2000 psi was used and also a flow rate of 30 ft/sec. The method is sensitive to local corrosion. O_2 appears to inhibit corrosion at this temp.

Investigation into the stress corrosion of some mild steels in natural environments A. Hache (*Rev. Mét.*, 1958, **55,** July, 656–678. Eight hundred specimens representing 5 grades of steel have been studied at 3 corrosion test stations over a period of 6 years. The results have shown clearly that the corrosion of mild steel is not affected by tension even up to the elastic limit. OH and basic Bessemer steels have been studied and the 3 test stations were in industrial, rural and marine areas.

The Flade potential of iron passivated by various inorganic corrosion inhibitors H. H. Uhlig and P. F. King (*J. Electrochem. Soc.*, 1959, **106,** Jan., 1–7) The potential observed just before the decay of passivity was measured for iron passivated with ferrates, nitrites, chromates, molybdates, tungstates, HNO_3 and by anodic polarization in H_2SO_4. This is linear with pH. A mechanism for this and for passivity itself is suggested.

The influence of plastic deformation on the corrosion of SG irons I. Cornea and S. Zamirca (*Studii si Cercetari de Metalurgie*, 1958, (4), 451–461) Grey and SG irons were investigated. The specimens were first rolled with different rates of reduction and only the rolled surfaces were exposed to corrosion in a 5% HCl and a 5% NaCl solution. The corrosion in HCl was found to vary with the degree of plastic deformation. Specimens tempered at 250° corroded more rapidly than those tempered at 600°, probably because at the lower temperature the internal stresses were not relieved. In NaCl the SG irons have a smaller corrosion rate than the grey irons, but the rate of corrosion is hardly affected by the degree of deformation.

The investigation of corrosion mechanisms with the X-ray microscope R. T. Foley (*Corrosion*, 1958, **14,** Nov., 531t–532t) Examples given are non-ferrous.

Laboratory and field methods for quantitative study of sulphide corrosion cracking J. P. Fraser, G. G. Eldredge, and R. S. Treseder (*Corrosion*, 1958, **14,** Nov., 517t–523t) Test apparatus and procedures for studying sulphide corrosion cracking are described; the method may have general applications in the broader field of stress corrosion cracking. The 'critical strain' of an alloy can be determined: it is the strain at which the probability of failure under specified test conditions is one-half, and is calculated by the statistical technique of probit analysis. By a modification of the method the 'severity rating' of various environments can be assessed.—D. L. C. P.

Marine research station: Anti-corrosive and anti-fouling paints studies (*Corros. Prev.*, 1958, **5,** Aug., 46–48) Work carried out at the ICI Paints Division Research Station at Brixham is outlined.

The behaviour of zinc coatings in marine conditions (*Corros. Prev.*, 1958, **5,** Sept., 45–48, 74) An account is given of the results of BISRA tests on Zn-coated specimens under marine conditions; a comparison of the results obtained with six other metal coatings showed the superiority of the Zn in respect of corrosion and fouling.

Influence of cathode and anode polarization on the rate of corrosion cracking in austenitic stainless steel V. V. Romanov and V. V. Dobrolyubov (*Metallov. Obra. Met.*, 1958, (7), 19–21) Specimens of 1Kh18N9 steel (0·01%C, 19·98%Cr, 9·95%Ni, 0·06%Ti) uniaxially loaded with 30 kg/mm² were immersed in a boiling 42% solution of $MgCl_2$. Findings show that at relatively low densities of cathode current the time to cracking is initially reduced and that it increases steeply as the current is increased to a certain value. Anode polarization increases the number of small cracks which spread. This is not observed at the cathode, nor is it seen in the absence of polarization.—L. R.

Humidity testing of protective finishes H. Melrose and R. E. J. Shave (*Corros. Prev.*, 1958, **5,** May, 49–54) Tests are described on the basis of which it is concluded that humidity test specifications should include a statement of temperature within close limits. Other factors affecting test conditions are discussed.

Investigations of white layers in pitting corrosion F. Ya. Iokheles (*Metallov. Obra. Met.*, 1958, (10), 28–33) The experimental findings show that high local pressures and intensive heating result in secondary hardening of microvolumes on the friction surfaces of low alloy Cr-Ni steels which shows as white layers (highly stressed austenite-martensite). These layers are susceptible to cracking and peel away, resulting in pitting corrosion.—L. R.

New investigations on the adsorption of hydrogen during the dissolution of iron L. Cavallaro, G. P. Bolognesi, and L. Felloni (*Werks. Korr.*, 1959, **10,** Feb., 81–86) The effect of adsorbed H_2 on the dissolution mechanism of Fe in acid media was studied. It was found that H_2 diffuses into the interior of Fe samples where a dynamic saturation equilibrium forms that is rate-determining. The effect of inhibitors on this phenomenon and consequently the protection given to the Fe was also studied.—T. G.

Inhibitors and passivators as corrosion inhibitors W. Machu (*Arch. Eisenhütt.*, 1959, **30,** March, 145–152) The anti-corrosive effect of inhibitors and passivators is due to the formation of pin-cushion-like layers on the metal surface. The energy liberated by adsorption or chemical bonds on the metal surface determines layer formation by adsorption, chemisorption, or passivation. The degree of protection is a function of bond strength, porous structure, and electrical resistance of the layer formed.—L. J. L.

The influence of volatile inhibitors on the electrochemical behaviour of iron I. L. Rozenfel'd and V. P. Persiantseva (*Doklady AN*, 1958, **122,** (2), 260–263) The effect of the volatile inhibitors benzylamine and morpholine on the corrosion-resistance of iron was studied. Curves showing changes of stationary potential of the iron electrode in relation to the actions of volatile inhibitors are given. The strength of the link between the inhibitor and the metal and its influence on the passivity of the metal are characterized by the curves of changes of the potential with time.—S. I. T.

Limitations on chemical means of controlling corrosion in boilers D. E. Noll (*Corrosion*, 1958, **14,** Nov., 541t–544t) Five examples of boiler tube failures caused by corrosion are discussed, and problems associated with modern temperatures and pressures are considered. Corrosion can occur in boiler tubes despite the use of chemicals in the boiler water, and it is concluded that under certain operating conditions periodic cleaning with acid is essential.

Current and potential relations for the cathodic protection of steel in salt water W. J. Schwerdtfeger (*Corrosion*, 1958, **14,** Oct., 446t–450t) A laboratory investigation on the cathodic protection of steel is reported, in which samples were exposed to tap water containing 3% NaCl. Major consideration was given to the significance of potential as a criterion for protection. Optimum protection was achieved when specimens were controlled at −0·77 volt with reference to the saturated calomel half-cell. Although a good degree of protection was obtained at controlled potentials more noble than −0·77 volt, that is, at potentials associated with the breaks in cathodic polarization curves, this lesser degree of protection could not be obtained at lower mean current densities.—D. L. C. P.

ANALYSIS

Determination of ferrous iron in materials containing metallic iron and ferric iron A. Kondô and Y. Fuke (*Nippon Kinzoku*, 1958, **22**, June, 286–290) A development of the $HgCl_2$ method is described which permits the accurate determination of ferrous iron in materials containing metallic iron and its oxides.—A. G.

Trilonometric determination of iron and aluminium in iron-aluminium bronzes M. I. Rosenberg (*Zavods. Lab.*, 1958, (9), 1060) The method used was evolved at the Ural Technical Institute for the determination of Fe and Al in iron and Al bronzes, in water, in deposits due to boiling and in vapours. Results obtained by this method agree closely with the analyses obtained by other chemical methods.—L. H.

Plasmoquin as a reagent in inorganic analysis. Detection of Cr (VI) Lee Te-Fung, Wang Nai-Ching, and Shen Nai-Kuei (*Acta Chim. Sinica*, 1958, **24**, (6), 403–406) A red colour is produced in presence of N/10 $HClO_4$ and 8% oxalic acid. not extracted by ordinary solvents. Ceric and vanadyl ions interfere but can be removed.

Determination of niobium in the presence of tungsten by means of cupferron A. I. Ponomarev and A. Ya. Sheskol'skaya (*Zhurn. Anal. Khim.*, 1959, (1), 67–70) The method consists of precipitating Nb with cupferron in a weak HCl solution in the presence of oxalic acid when a complex compound is formed with W. Thus this method does not require a preliminary separation of Nb and W.

Successive determination of iron, copper and titanium in ferro-titanium by the chromous chloride method A. I. Busev and Li Gyn (*Zavods. Lab.*, 1959, (1), 30–34) The usual method of titration of the quadrivalent Ti with a solution of chromous chloride does not give satisfactory results because, on the curves, the jump in potential during electrolysis is not clearly apparent. The new potentiometric method suggested is as follows: 1 g Fe–Ti is dissolved in hot H_2SO_4 (1 : 5) and a 30% solution of H_2O_2. When the solution is light green, permanganate solution is added until pink and boiled, cooled, and transferred to a 250 ml measuring flask and made up with distilled water, 50 ml are then titrated. With an indicator electrode clamped to the positive terminal and a calomel electrode to the negative, CO_2 is passed through the solution, after which titration is begun with chromous chloride using a Pt indicator electrode. The first jump in potential occurs when Fe^{III} is reduced to Fe^{II} after which the second jump is noticed corresponding to the reduction of the bivalent to the monovalent Cu. 80–100 ml concentrated HCl saturated with CO_2 is added, the electrode replaced by a mercury electrode in the form of a cup, and titration is carried out between 60–70°. The third jump in potential occurs after the complete titration of Ti.

Indirect polarographic and complexometric analysis of small quantities of arsenic in pig iron and ores A. Černy (*Hutn. Listy*, 1958, **13**, (8), 715–716) Arsenic is present in blast-furnace raw materials in relatively small quantities and its continued presence in pig iron and steel has an extremely harmful effect on the further working of the material. Existing methods of analysis are laborious and inaccurate, and it is worth adopting the methods indicated above. On the basis, of the laboratory experiments described, a method was evolved on the basis of distillation and precipitation of As_2S_3 with hydrogen sulphide. The precipitate, after weighing, is dissolved in a measured quantity of $CdSO_4$. The excess $CdSO_4$ is determined polarographically or complexometrically.—M. T.

Applicability of Knorre's method. On the determination of Ce in steels. I K. Sekimoto and K. Kosahara (*Tetsu to Hagane*, 1958, **44**, June, 674–678) The work on stainless steel treated with mischmetall concerns the separation of all rare-earth metals using HF solution and the application of Knorre's method to Ce in the separated rare earths.—K. E. J.

On the determination of Ce in steels. II. On separation of hydroxide, extraction with amyl acetate and colorimetry with oxine K. Sekimoto, H. Matsumoto, and K. Oda (*Tetsu to Hagane*, 1958, **44**, July, 762–767) Knorre's method has the disadvantages of a limit of 1 Mg for determining Ce and the need to take samples as large as 5 g. To determine micro-amounts of cerium in stainless steel, the rare earths are separated as oxides and cerium is separated as the hydroxide. A purified oxide is dissolved in acid, extracted with amyl acetate and determined colorimetrically with oxine.—K. E. J.

Photometric determination of copper in iron and steel by means of diphenylcarbazone L. N. Lapin and N. V. Reis (*Zhurn. Anal. Khim.*, 1958, **13**, (4), 426–429) The copper derivatives of diphenylcarbazone are insoluble in water, slightly soluble in amyl alcohol, ether, carbon tetrachloride and very soluble in benzene and its homologues. The intensity of the red colouring of the solutions obeys the Lambert–Beer law. The method described is very sensitive and quite specific. The margin of error is below 4%.—L. H.

Gravimetric determination of lead in iron and steel (lead content > 0·05%) BISRA Methods of Analysis Committee (*JISI*, 1959, **193**, Dec., 350–353) [This issue].

Spectrochemical determination of magnesium and its influence on the analysis of silicon and manganese in cast iron A. S. Demyanchuk and E. D. Kukharenko (*Zhur. Anal. Khim.*, 1959, (1), 45–49) A spectrographic method is described for determining Mg in inoculated cast iron by means of a high-frequency spark as source of excitation. Determination of a content of 0·005% is possible. The intensity of the Si and Mn spectral lines depend on the Mg content and increases with the Mg content. Should this exceed 0·6%, the intensity is 1½–2 times that corresponding to the actual content of Mg. By using a special oscillator of type IG–2 the presence of Mg does not influence the spectral determination of Si and Mn.

Spectrographic determination of magnesium in SG cast irons J. Buzincu and M. Nicolaid (*Studii si Cercetari de Metalurgie*, 1956, (1), 217–228) [In Rumanian] Tests for the spectrographic determination of Mg (between 0·02–0·115%) by the three or by the one standard methods have shown that determinations can be made with a precision which is far beyond the one obtainable by chemical analysis. It has also been shown that the one-standard method can be used to obtain results very close to the three-standard method.

Polarographic analysis of small quantities of zinc in ferro-manganese and manganese containing cobalt S. Kral and B. Kysil (*Hutn. Listy*, 1958, **13**, (8), 716–717) A method was sought for accurately determining zinc contents up to 0·10%. A specimen was prepared by alkaline oxidation-reduction, and after leaching and filtering off the precipitate containing Co, Mn and other elements, Zn remains in the filtrate as a zinc salt. After preparing a solution, Zn is polarographically analysed in an ammoniacal medium.—M. T.

Rapid analysis of cupola slag B. Bieber and Z. Vecera (*Prz. Odlew.*, 1958, **8**, April, 66–73) The procedure of preparing samples and chemical analysis are described in detail. The time of the slag analysis is shortened to 2 h.

An infra-red drier for rapid moisture determinations E. A. Willis (*Refractories Inst. Techn. Bull.*, 1958, Oct., (100), pp.7) The construction of the drier is shown in detail and components are listed. Tests on fireclay showed that with 375-watt bulbs nearly all the moisture is removed in 10 min and drying is complete in 15.

Problems involved in analysing iron ore sinters J. A. Berger and S. H. Klinvex (*Blast Furn. Steel Plant*, 1958, **46**, July, 698–794) The results of chemical analyses carried out by a number of different laboratories on standard sinters are described in detail. They show that analytical techniques commonly used for sinter analysis require further study as erratic results have been obtained for the majority of the components.—B. G. B.

Rapid determination of silica and iron in chrome ores H. Grubitsch (*Radex Rund.*, 1959, (1), 460–461) The gravimetric method described for the determination of SiO_2 in Cr ores takes about 5 h, and the accuracy is comparable with that obtained with a standard method. The solution contains gelatine, but this does not interfere with the subsequent determination of Fe.

Determination of total Fe, TiO_2 and FeO. (Study of the chemical analysis of sand iron and ilmenite – I) S. Wakamatsu (*Tetsu to Hagane*, 1958, **44**, Oct., 1197–1203) The author suggests a scheme for the rapid chemical analysis of iron ores, in particular ilmenite for Ti, and gives that scheme as a diagram with English captions. Total Fe and TiO_2 are determined in the same solution by titration with $KMnO_4$ with $NaWO_4$ as indicator. Accuracy was satisfactory.—T. G.

Simultaneous potentiometric determination of molybdenum and tungsten in special steels R. Suarez Acosta (*Inst. Hierro Acero*, 1958, **11**, Oct.–Dec., 282–286) The method is based on preliminary reduction of Mo and W with Zn and chromous sulphate, followed by oxidation with standard $K_2Cr_2O_7$.

Studies on the extraction and determination of metal salts with methyl isobutyl ketone. I. Extraction from acid solution H. Goto and Y. Kakita (*Sci. Rep. Res. Inst. Tohoku Univ.*, 1959, **11A**, (1), 1–20) Fe, Sb, As, Se, Te, Ge, Cr, V, Mo, Mn extractions are investigated.

Rapid analysis of alloying elements in iron and steel by photoelectric colorimeter. I. T. Ando, H. Kato, K. Ito, and K. Katayama (*Toyo Kohan*, 1952, Nov., 42–48) [In Japanese] An improved colorimeter uses a stable light source built with an LC voltage stabilizer and ballast lamps. For N, the micro-Kjeldahl steam-distillation method is used; results are rapid and agree with standard methods. The colorimetric method described for Si is more accurate than the gravimetric.—K. E. J.

The determination of small amounts of aluminium in cast iron R. C. Rooney (*BCIRA J. Res. Dev.*, 1958, **7**, Dec., 436–441) A spectrophotometric method is described for determining Al in amounts below 0·1%. After removing iron and other interfering elements the Al is extracted as cupferrate, organic matter is destroyed, and Al is determined spectrophotometrically with 8-hydroxyquinoline in chloroform.—A. G.

The determination of magnesium in nodular graphite cast iron R. C. Rooney (*BCIRA J. Res. Dev.*, 1958, **7**, Dec., 442–445) A rapid stoichiometric method for determining Mg in nodular cast iron is described. Iron and other interfering elements are removed by extraction processes and the Mg is titrated at pH10 with EDTA.—A. G.

Comparative tests on some instruments used in absorptiometric methods of analysis W. E. Clarke (*BCIRA J. Res. Dev.*, 1958, **7**, Dec., 360–391) The applications of the Hilger Uvispek and Spekker instruments and the EEL absorptiometer in the routine analysis of cast irons are examined and performances compared. Conditions are summarized for the routine determination of 11 elements.—A. G.

Metallurgical absorptiometry and spectrophotometry. III. E. C. Pigott (*Murex Rev.*, 1959, **1**, (20), 606–623) Commercial equipment and processes are reviewed.

Steel quality control using the ARL quantometer H. C. Brown (*J. Metals*, 1958, **10**, Dec., 815–816) A brief outline is given of the results obtainable by the use of the ARL Production Control Quantometer in the analysis of plain carbon and alloy steels.

Spectrophotometric and photometric microdetermination of vanadium F. B. Martinez and M. P. Castro (*Chem.-Analyst.*, 1959, **48**, Mar., 2–3) Ethylene glycol bis-(β-aminoethyl ether)-*NNN'N'*-tetra-acetic acid and H_2O_2 are used.

Spectrometric analysis of basic Bessemer pig iron by the scanning slit method M. D. E. Jonkers and A. Daniels (*Rev. Mét.*, 1958, **55**, July, 601–612) For routine analysis of C, Mn, P and Si a prism spectrograph with a scanning slit has been used. The analysis is performed using either a spark discharge or a continuous arc with a polychromatic reflected beam as a standard. Full details are given of the sample preparation and operation of the spectrometer. Practical results are discussed.—B. G. B.

BOOK NOTICES

AMERICAN VACUUM SOCIETY. *'Glossary of Terms used in Vacuum Technology'*. 9½ × 7 in., pp. iii + 63. 1958, New York, London: Pergamon Press Ltd. (Price 10*s*.)

A short Glossary which represents an attempt by the American Vacuum Society to achieve a standard nomenclature in a rapidly growing branch of technology. It has been under discussion in the United States as a draft for some years but it must still be regarded as tentative in that country until it is approved or amended by the American Standards Association. Discussions have taken place with the Committee of The British Standards Institution, which produced the British Standard Glossary (B.S. 2951: 1958), and in both countries efforts have been made to obtain as much agreement as possible although, as was almost inevitable, a fairly small number of differences remain which are indicated in the British Standard.—M. L. PEARL.

BASHFORTH, G. REGINALD. *'The Manufacture of Iron and Steel'*. Volume II, *'Steel Production'*. Second edition revised. 8½ × 5½ in., pp. viii + 390. Illustrated. 1959, London: Chapman and Hall Ltd. (Price 40*s*.)

Since Mr Bashforth is preparing a third volume of his classic, under the title *'Fuels, Furnaces, Refractories and Instruments*, the second edition of this volume is 71 pages shorter and five shillings cheaper than the first. With those omissions, its contents are basically the same, descriptions of steelmaking methods, one by one; although the chapter arrangement is different—for instance, Ch. 13, *Blister Shear and Crucible Steel* now appears word for word as Ch. 1—the new material is, almost everywhere, supplementary to the old, and consists of descriptions of newer methods. None of the older material has been removed, and very little re-written in the light of modern knowledge. The book therefore presents a somewhat conservative picture of the industry and its processes: the retention of all the earlier illustrations tends to emphasize this.—J. P. SAVILLE.

BETTERIDGE, W. *'The Nimonic Alloys'*. 9 × 6 in., pp. xii + 332. Illustrated. 1959, London: Edward Arnold (Publishers) Ltd. (Price 80*s*.)

Nimonic alloys have become synonymous with high temperature strength, particularly in gas turbine applications. No one is better acquainted with the development of these series of alloys than Dr Betteridge, and therefore, as would be expected, this is a valuable text book.

The author covers briefly the theory of creep resisting alloys and discusses the constitution of the Nimonic alloys by reference to ternary and quaternary phase diagrams of the various constituents. A noteworthy feature of the Nimonic alloys is the similarity of the lattice parameter of the face centre cubic matrix to the precipitation hardening phase $Ni_3(AlTi)$. This phenomenon is thought to explain the excellent stability and creep strength of these alloys. The processing of the Nimonic alloys is described in great detail, and the coverage includes melting, hot and cold working, heat treatment, machining, joining, and inspection. The wealth of detail given on each of the relevant processes make this book invaluable to anybody concerned with the production of components made in the Nimonic series. The physical and mechanical properties of the alloys are dealt with just as adequately and again all concerned with the application of Nimonic alloys in high temperature engines should find this text book of considerable use.

One is, however, tempted to criticize one aspect of this publication. The importance of trace elements such as boron and zirconium has been reported by many authors both in the U.S.A. and in the U.K., and it is somewhat surprising, therefore, that such an important subject in the manufacture of nickel base alloys should receive no mention at all. This omission is undoubtedly due to reasons of commercial security, but it makes the book of less interest to the metallurgist concerned with high temperature alloy development who might have looked for some of the explanations and achievements which can be obtained by the control of trace element additions. One wonders, perhaps, if this somewhat unfortunate omission may be remedied in future editions.—H. C. CHILD.

BUCHER, G. *'Drahtseile und Ihre Herstellung'*. 8½ × 5½ in., pp. 105. Illustrated. 1958, Berlin: VEB Verlag Technik. (Price DM. 7.60.) SHITKOV, D. G., and POSPECHOW, I. T. [Zhitkov, D. G., and Pospekhov, I. T.]. *'Drahtseile'*. [German translation from the Russian. *'Stal'aye Kanaty Dlya Pod'emno–Transportnykh Mashin'*.] 9½ × 6¾ in., pp. 350. Illustrated. 1957, Berlin: VEB Verlag Technik. (Price DM.23.)

Text books on the subject of Steel Wire Rope manufacture and design are not numerous, and therefore these works (at present available only in German) will be of special interest to those concerned with the fabrication and use of this product. Bucher, much the smaller of the two, deals in a relatively simple and general way with current practice in Eastern Germany. Although it does not shed any new light on standard methods, it can be a useful addition to the library of manufacturers, and can also serve as a practical guide for users in determining the most suitable construction to be employed for any particular purpose. *'Drahtseile'*, a translation into German from the original Russian is, on the other hand, a book of exceptional value. In addition to covering fully modern practice in this field, the chapters on design, manufacture, testing and application, are most enlightening. On design, it is obvious that the authors have been very thorough in appreciating the importance of accuracy in calculation. Throughout several chapters, new theories are expounded which will be of particular interest to leaders in this field in other countries. Much effort has gone into the simplification of complicated calculations by the use of nomograms. Of special note are the sections dealing with the theory of Wire and Strand Helix Pressures in Ropes under working conditions, because this has a direct bearing on the stable apparent rope modulus, which in turn controls the useful life of a rope. This theory is of considerable importance, and although freshly explored by this work, was a factor which was well appreciated by rope-makers in the past, under the term of 'cross-bearing' or 'bridging'. Of special interest are two chapters dealing effectively with the practical aspect of rope-making. One is devoted to pre-forming and the other to post-forming. On both of these, new definite views are advanced, which are based on technical calculations. Apart from this, the whole nature of manufacture is dealt with thoroughly. In the field of testing, it is plain that Russian methods have kept pace with those used in the Western World, and this book contains interesting information on current practice, particularly with regard to fatigue. In this sphere, particular emphasis is laid on the need to correlate test evaluations with rope design and useful suggestions are made in this respect. Finally, this book comments authoritatively on the problems relating to application in the field. The authors' figures on the effect of sheave [illegible]le design in relation to useful rope [illegible]erit careful study in respect of lay [illegible]h and wire contact length on the sheave profile. In addition, other information on general problems of application should prove very useful to the informed rope user.—C. R. W. HUGHES.

CAZAUD, R. *'La Fatigue des Metaux'*. 4th edition, 9½ × 6 in., pp. xvii + 574. Illustrated. 1959, Paris: Dunod. (Price 6900 F.)

This notable book, with which English readers are most familiar through Fenner's translation of the third (1948) edition (see *JISI*, 1953, **174**, July, 302) is, in its present form, some 80% longer than ever before. Comparison of one with the other shows that, though the general form and the chapter headings have been largely preserved, the text in all parts has been amended and extended to take note of all recent developments in the subject of fatigue; although the date of M. Cazaud's preface is December 1958, there are references as late as September of that year.—J. P. SAVILLE.

CHASSUIN, G. *'Manuel des Traitements de l'Acier'*. 8½ × 6 in., pp. vii + 124. Illustrated. 1959, Paris: Dunod. (Price 680 F.)

This is a simple book on the manufacture and heat-treatment of carbon and alloy steels. Two brief final chapters deal with surface treatment and anti-corrosion protection.—J. P. SAVILLE.

COATES, V. J., NOEBELS, H. J., and FAGERSON, I. S. (Editors). *'Gas Chromatography'*. A Symposium held under the auspices of the Analysis Instrumentation Division of the Instrument Society of America, 1957. 9½ × 6½ in., pp. xii + 321. Illustrated. 1958, New York: Academic Press Inc. (Price $12.00.)

This is a most interesting symposium, and while it deals with no applications of direct interest to the steelmaker it is obviously an analytical method to be kept in mind, even though the 'instrument for high temperature gas chromotographic analysis' described by B. W. Taylor (155–164) only operates, so far, up to 300°C. Much of the symposium is theoretical, dealing with the mechanism of separation. The obvious immediate application might be to the analysis of lubricants or anti-corrosive agents, perhaps to waste gases; effluents, volatiles liberated on heating from metal or slags: problems of this type constantly arise and it is as well to be acquainted with any technique which might give the answer. Such things as the analysis of oil fuels might also be susceptible to continuous monitoring by some modification of the technique. The use of metal salts as column liquids is described by C. Phillips (58–61); could these be examined by the separations they effect, or could molten fluxes or slags replace the fused salts? It is not perhaps for the busy steelworks chemist to pursue these possibilities, but something of the sort lies, no doubt, in the future.

We would suggest the perusal of this excellent collection of papers to the analyst, no matter how busy he is, if only as an escape from routine or, at the best, as a gateway to a further advance in the practice of his science.—J. G. COCKBURN.

EMINGER, Z., and KOŠELEV, V. *'Cast Tools'*. Translation from the Czech edition by Ch. Čáslavaský and G. A. Evans. 8 × 6 in., pp. 230. Illustrated. 1958, London: Constable & Co. Ltd. (Price 20*s*.)

The theme of the book is the economic and satisfactory production of cast high-speed steel milling cutters using an inverting, modified indirect arc electric furnace with detachable mould for the actual casting operation. In the scheme described the entire contents of the furnace are used to cast one set of milling cutters, these varying in weight from 1 to 40 kg per cutter. It is claimed that the largest cast tools produced by this method have shown better service qualities and longer service time than the same tools made from forgings. At the same time a yield of 80% of ingot weight is claimed for the finished tool, as opposed to a yield of less than 30% for a similar tool produced from a forging.

Printed in Czechoslovakia, this book contains grammatical mistakes and errors in punctuation; spelling mistakes appear on almost every page. But in spite of the sometimes unrecognizable English used, this is an important book, for it describes a manufacturing method unknown in this country. Coupled with one of the newer, and

successful methods of heat treating high-speed steels, cast tools produced by the methods described could rapidly overtake conventional production from forgings. From the figures quoted for capital equipment it is obvious that pilot plants would cost very little; indeed, the smaller units, of about 3 kg could safely be operated on the normal AC output from a welding set. It is claimed that this method of cast tool production is being introduced on a wide scale in Czechoslovakia.

The book has chapters on the properties of steel, comparison of cast and forged steel, tool casting, production methods in tool casting, high-speed steels, heat treatment, machining and service results of cast tools, cost finding considerations, theoretical analysis of heat treatment and the structural analysis of cast tools.—W. G. SALISBURY.

FINNIE, I., and HELLER, W. R. '*Creep of Engineering Materials*'. 9 × 6 in., pp. ix + 341. Illustrated. 1959, New York, Toronto, London: McGraw Hill Publishing Co. Ltd. (Price 89*s*.)

Numerous technological advancements require the use of materials at ever increasing temperatures. In fact there are instances where progress has been halted for lack of a suitable material. For existing high temperature alloys, however, the design engineer is faced with problems which rely for their solution on creep characteristics. But the application of creep data to a specific design may prove to be a most complex undertaking and the position is made more difficult by the fact that design for creep conditions is not generally included in engineering training. The book under review fills this real need and should be of great value to designers of high temperature machines. It is the only single available source which deals in a comprehensive manner with existing knowledge of creep calculations.

The heart of the book is a series of three chapters on stress analysis under various creep conditions including the complex problem of non-steady-state multi-axial creep and one chapter on the choice of a design stress. The authors deal fully with these problems and give a complete list of references at the end of each chapter. This would have made the book complete without much of the additional material such as a chapter on dislocation theory and another on creep measurements. Such material is already available in a number of earlier publications and is not after all of direct interest to the design engineer for whom the book was written. The book ends with a stimulating chapter on specific applications.—A. H. MELEKA.

FRITZSCHE, C. '*Wörterbuch des Hütten—und Walzwerkwesens. Russisch–Deutsch*'. 8 × 5¼ in., pp. 387 [+34]. Illustrated. 1955, Berlin: VEB Verlag Technik. (Price DM. 33.)

In its presentation this Russian–German dictionary of metallurgical and rolling mill terms is in many ways a model work. There are wide margins, giving space for addenda; chemical formulae are given where appropriate and, in the case of the elements, their atomic weights and numbers, specific gravities and melting points. Where phrases of the type 'creep curve', 'continuous furnace', are given–and there are many of these—each begins on a new line. A specially useful feature is the series of 38 drawings, ranging from a blast-furnace to hand-forging tools: the parts of the machines, etc., are numbered, and the key numbers are given under the appropriate words in the text.

It is of course possible to find omissions, of which perhaps the most surprising is 'continuous casting', which ought surely not only to be included, but to have its own diagram; the special term for a continuous casting mould ('kristallizator') is, however, given. Comparison with Callaham's well-known *Russian-English Technical and Chemical Dictionary*, for example, shows that each work contains many words, of the kind which might occur in metallurgical literature, omitted from the other.

This dictionary, and especially its diagrams, should prove very useful to German speakers.—M. WRIGHT.

GENTZSCH, G. '*Fachbibliographie der Bildsamen Formung der Metalle*. Band 4, Schmieden und Pressen. 8 × 6 in., pp. 299. 1958, Berlin: Akademie Verlag. (Price DM. 19.)

This bibliography of 1224 references to the forging and pressing of metals covers not only those subjects themselves, but the plant employed, its auxiliaries, such as dies, and the necessary heating furnaces. The abstracts are a little mixed in style, varying from phrases without verbs to sentences of true Germanic complexity, but the references are fully given, with titles in the original language (when not German) as well as in German. They are arranged according to the Universal Decimal Classification.—J. P. SAVILLE.

KRÜGER, C. L. '*Guide Industriel de la C.E.C.A.* [*Industrial Guide to the European Coal and Steel Community and its Ancillary Industries*] Vol. I, 1959. 11½ × 8¼ in., pp. 1200 (approx.). 1959, Dortmund. (Price $30.00.)

This volume is divided into five parts, the first of 17 pages entitled 'Organization of the European Communities' and covering the Coal and Steel Community, the Economic Community and Euratom, the second of 52 pages dealing with the Mining Industry within the European Coal and Steel Community, the third of 129 pages with the Iron and Steel Industry (here, divided by country, the iron and steel undertakings are listed and described), the fourth, of nine pages only, with the Scrap Trade, and the fifth of 546 pages with chemical metallurgical, textile and engineering products, divided by country and manufacturer. There are also about 800 full-page, half-page and quarter-page advertisements on art paper with a separate index. Every attempt has been made to present the descriptions, subject headings and so on, in English, French, German and Italian; one cannot, of course, criticize the other three languages, but there is a great deal of clumsy and inaccurate English. This slightly disfigures an otherwise very useful compilation.—J. P. SAVILLE.

GÜNTHER, E. '*Herstellung Warmgewalzter Feinbleche*. 2 Auflage. 9¼ × 6½ in., pp. 326. Illustrated. 1958, Berlin: VEB Verlag Technik. (Price DM. 24.)

The first edition of this book on the production of hot rolled thin sheet, which appeared in 1957, dealt solely with sheet mills, taking sheet bars as their raw material and reducing them in conventional manner, though with all the benefits obtained from such developments as mechanical mills and the like. Thus the book covered the whole flow of production, from sheet bar to the rolling stand, the rolls and their maintenance, the elements of hot rolling and the engineering aspects, through to the final stages of annealing, pickling and flattening.

This second edition retains the earlier material, which is now supplemented by a chapter, some fifty pages long, devoted to the production of wide sheet on hot strip mills. This gives quite a detailed account of equipment, working conditions and rated outputs. The author's argument is that while the number of strip mills is steadily growing—although as yet none exists in Eastern Germany—there still remains a considerable share of the sheet market which can best be met by sheet mills. Fully mechanized mills are able to produce stainless and other high-grade steels, as well as sheets to special dimensions, in an economic fashion, especially where order sizes are small. If this opinion is tenable, then a book of this nature may well be considered of value, since it is comprehensive and reasonably well illustrated, although few literature references are given. Otherwise, if sheet mills become increasingly uncompetitive and go progressively further out of production, then this work will become of mainly historical interest.

A useful compilation of German standards for thin sheet is provided, including special grades and methods for their physical testing.—R. A. HACKING.

ROLL, F. (Editor). '*Handbuch der Giesserei-Technik*'. Erster Band/1 Teil. 10½ × 7½ in., pp. xvi + 892. Illustrated. 1959, Berlin: Springer-Verlag. (Price DM. 136.)

To describe this work as stupendous is no exaggeration, particularly in these days when superlatives seem inadequate in the realms of science. This magnificent book, edited by Professor F. Roll, runs to 880 pages but is only the first of two parts comprising Volume I. The complete work promises to have four volumes which must make it the most comprehensive tome ever written on Foundry Technology. It is a great pity that it is written in German which will seriously limit its usefulness in Britain.

The 'Handbook' reviews the rapid developments which have taken place in the ferrous foundry during the last twenty or thirty years. Specialists have contributed separate sections but the book is not disjointed because of this. Firstly, we read of the developments in the general science of metals, then follows basic principles of foundry practice, raw materials, testing and surface treatments, concluding with a chapter on welding. A generous space is devoted to art castings for which the German founder is famous. There is a good account of moulding materials and a comprehensive list of properties of European sands. The sections on malleable iron and steel castings are also well written. Laboratory practice, including chemical and spectrographic analysis, is specially featured. Although, naturally enough, the specialist contributors are all German, they have combed the world literature to give very complete reviews of their subjects. In the index of literature references, a few minor errors have escaped the proof reader but the presentation in the main text is remarkably accurate and thorough.

The book is well bound and costs about ten guineas. Those who can afford such a comprehensive work of reference will await with pleasurable anticipation the publishing of the remaining parts.—R. V. RILEY.

GUY, A. G. '*Elements of Physical Metallurgy*'. 2nd ed. *Metallurgy and Materials Series*. 9 × 6 in., pp. xvi + 528. Illustrated. 1959, Reading, Mass.: Addison-Wesley Publishing Co. Inc. (Price $9.50.)

This is a new edition of the text book on the fundamentals of physical metallurgy, first published in 1951. Intended primarily for science, engineering and metallurgy students, who are assumed to have some knowledge of chemistry and physics, together with a good grounding in mathematics, it is designed to be read in conjunction with a course of lectures on the subject. Its usefulness is not confined to such readers, however. Graduates, professional engineers and metallurgists wishing to know how the subject is expanding and developing, will find much to interest them in this admirable book, which contains a wealth of information, clearly and intelligently presented with the aid of cleverly constructed diagrams and tables. The mathematical treatment of some aspects of the subject may be found rather difficult, but it can generally be skipped without significant loss, because the conclusions from the theoretical treatment, and their practical applications, are mostly set out with commendable clarity. The original edition was an excellent 'digest' of existing knowledge and views concerning the more important aspects of physical metallurgy. The new edition contains so much new material, and the old material has been so carefully revised and brought up to date, that it is virtually a new book, resembling but even better than its predecessor.

Following a brief introduction, there is a chapter, for the benefit of newcomers to the subject, tracing the development of metallurgical knowledge and practice, and outlining typical processes of extracting, refining and forming metals. It is followed by two chapters (76 pages) on atomic and

crystal structures, including an introductory treatment of dislocation theory, then by 130 pages on phases in metal systems and on the interpretation and applications of equilibrium diagrams. After a brief survey of the electrical, magnetic, thermal and optical properties of metals, there are 80 pages on elasticity, plasticity and mechanical properties. The remaining 130 pages deal with theoretical and practical aspects of a variety of topics, including corrosion, diffusion, recrystallization, grain growth, age hardening, and the heat treatment of steel.—M. S. FISHER.

'*Handbuch der Härteprüfungen Nach Brinell, Rockwell, Vickers*'. 8 × 5¼ in., pp. 136 + 70. Illustrated. 1959, Esslingen/Neckar: Georg Reicherter. (Price DM. 12.50.)

This little book is in two parts, the first describing the penetration hardness testing machines made by the firm of G. Reicherter, under the names of 'Briviskop', 'Briro', and so on, the second reproducing standard tables relating hardness to diameter of impression, load, etc., for Brinell, Vickers and Rockwell machines.—J. P. SAVILLE.

HINSLEY, J. F. '*Non-Destructive Testing*'. 8¾ × 5½ in., pp. xxxiv + 495. Illustrated. 1959, London: MacDonald & Evans Ltd. (Price 75*s*.)

The first comment one must make about this book is that it would be much improved by ruthless editing. The author should have decided at the beginning for whom the book was intended, and written in accordance with some assumptions about the technical standard of the reader. One does not expect to find, as on page 81, a step-by-step solution of the equation $\frac{dI}{I} = -\mu dt$, nor is there any justification in a specialist text book for half a chapter on the art of report-writing. It is a pity too that the author has not followed his own dictum on brevity (page 452) for as he says 'The net result is a certain irritability towards the author . . .'.

The technical content of the book, however, has much of interest to the reader prepared to look more deeply. The art and science of industrial radiography is fully covered and, in common with the rest of the contents, is well illustrated with line drawings and photographs. The treatment of ultrasonics and of magnetic and eddy-current methods of testing is less extensive but still adequate. It is useful to find a note (page 242) on the rationalized m.K.s. system of units, since, as the author points out, this system is not as familiar as the c.g.s. to the older industrial scientist. The effect is marred, however, in the following chapter by duplications of units and terms on both systems.

A few inaccuracies have occurred in the book. One micron is not 10^{-3} cm (page 69) and Fig.10.31a is not necessarily a differentiating circuit as the time constant is unspecified. In conclusion one can only regret that a book of such potential value to the ferrous metallurgist and to the N.D.T. specialist should have the handicap of an annoying presentation.—B. O. SMITH.

KOSSMANN, W. '*Edelstahl*', 8½ × 6 in., pp. 237. Illustrated. 1959, Düsseldorf: Verlag Stahleisen m.b.H. (Price D.M. 18.)

Divided into three sections, 'Foundation Stones', 'Milestones', and 'Keystones', this volume covers the history, composition and production of tool-steels, and the development and economics of the German tool-steel industry. The emphasis is greatly on the latter, and on the individuals, companies and trade-groups concerned, which are treated in immense detail. It is by no means a book for metallurgists only, but a deep and wide survey of a metallurgical industry which should interest many others.–J. P. SAVILLE.

KULIKOW, I. S., and POPOW, I. A [Kulikov, I. S., and Popov, I. A.] '*Radioaktive Isotope in der Metallurgie*'. [Translation from the Russian, '*Primenenie Radioaktivnykh Izotopov v Metallurgii*']. 8 × 5¾ in., pp. 304. Illustrated. 1959, Berlin: VEB Verlag Technik. (Price DM. 21.)

In this German translation of a Russian work, the authors' aim is to give a systematic treatment of the principles underlying the use of radioactive isotopes and their application to problems encountered in iron and steel making. It is not intended for specialists in tracer methods but rather for metallurgists who wish to become more familiar with this powerful technique.

The opening chapters outline the background of atomic physics which is needed by one who wishes to apply tracer methods intelligently and with safety. Useful data about the more commonly used isotopes are also given at this stage. The next section deals admirably with methods of measurement, procedures for calibration and methods of allowing for absorption effects in the sample. As an introduction to practical problems the determination of thermodynamical constants, such as vapour pressure, or coefficients of diffusion is described in some detail. The main part of the book is devoted to the application of tracer techniques in iron and steel works, both at the laboratory and works production stages.

The Russian and foreign literature of the subject is reviewed. Topics include the kinetics of the chemical reactions between metal and slag, the diffusion of iron in acid slags, and the reactions between iron oxide and refractory materials. The book ends with a chapter on the precautions necessary for the safe handling of radioactive materials. An extensive bibliography has been further expanded by the editor of the German edition, who has thoughtfully added an index. The book is concise and makes straightforward reading. It can be recommended to metallurgists who desire a more detailed knowledge of the subject.—T. MULVEY.

LIKHTMAN, V. I., *et al. Effect of a Surface-Active Medium on the Deformation of Metals*'. [Translation by D.S.I.R. from the Russian, '*Vlizanie Poverkhnestno-Aktivnoi Sredy na Protsessy Deformatsii Metallov*, 1954']. 8 × 6½ in., pp. viii + 188. Illustrated. 1958, London: H.M.S.O. (Price 15*s*.)

The steady erosion of the scientific and technological Iron Curtain, by the process of translation, must be welcome by all concerned. The literature translated from the Russian may take the form of individual original papers, abstracts or even complete journals. But a monograph is the best means of conveying a single theme in a comprehensive manner. The D.S.I.R. should be congratulated for taking the initiative in producing this excellent translation of a monograph on an interesting and important phenomenon. The appearance of further publications in this series will be awaited with interest by many Western scientists.

The monograph describes original researches into the interaction by adsorption between deformed metals and the surrounding medium containing a surface-active agent. Studies on the effect on the yield of metals, fatigue strength and creep strength are reported in great detail—in many cases using elementary and repetitive methods of presentation. The work is essentially experimental and only modest, perhaps unsatisfactory, attempts are made to explain the effects in terms of fundamental concepts. Nevertheless, it shows quite conclusively that the role of a surface-active medium cannot be ignored in such fields as metal working, lubrication and fatigue.–A. H. MELEKA.

POUNDS, N. J. G. '*The Geography of Iron and Steel*'. 4½ × 6¾ in., pp. 192. Illustrated. 1959, London: Hutchinson University Press. (Price 10*s*. 6*d*.)

Professor Pounds, already known to *Journal* readers as the author of '*The Ruhr*' and part-author of '*Coal and Steel in Western Europe*' (see *JISI*, 1959, **191**, Jan., 107) has now written a small but comprehensive book on the iron and steel industry of the world. For his historical material he has used and used carefully, well-tried sources, as his copious chapter-bibliographies indicate, and he is fully aware of modern economic developments, as witness his references to the Dutch works at IJmuiden and the French plant at Dunkirk, but recent technical developments, such as continuous casting and oxygen steelmaking, which may markedly affect the economic pattern, do not receive sufficient consideration. Nevertheless, within its limits and in accordance with its purpose of presenting a view of the world's ferrous industry, its present locations and the reasons why it is there, this is an excellent little book.—J. P. SAVILLE.

'*Refractories Bibliography*, 1947–1956'. Compiled by the Joint Refractory Committee of the American Iron and Steel Institute and The Refractories Institute. 10½ × 7¾ in., 1772 cols. + [50 pp.]. 1959, Norman: University of Oklahoma Press. (Price $7.50.)

This Bibliography for the ten years 1947–56 is a worthy successor to the previous volume which covered a twenty-year period, 1928–47. Over 9500 abstracts from the periodical literature and U.S. foreign patents relate to raw materials, manufacture, and properties and uses of refractories, and cover all types of industrial activity. The abstracts (reproduced from eleven different sources, two from the United States, and nine, including this *Journal*, from Britain), are arranged by authors in alphabetical order. There are numerous cross-references in an extensive subject index. Altogether, this is a first-class piece of editorial work of great value to all concerned with refractories.—M. L. PEARL.

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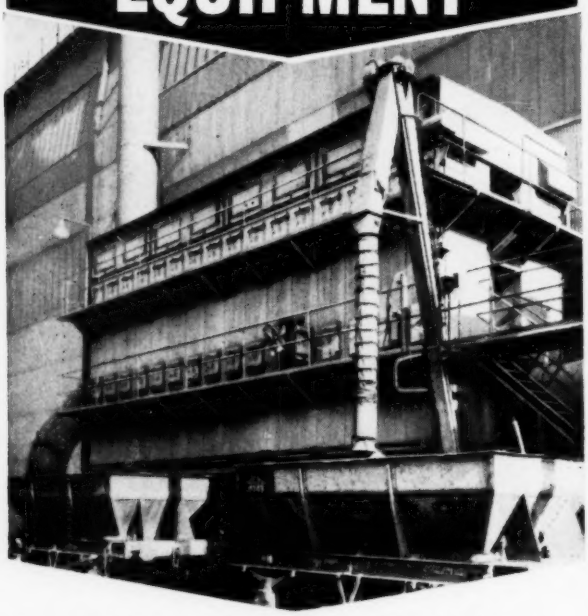

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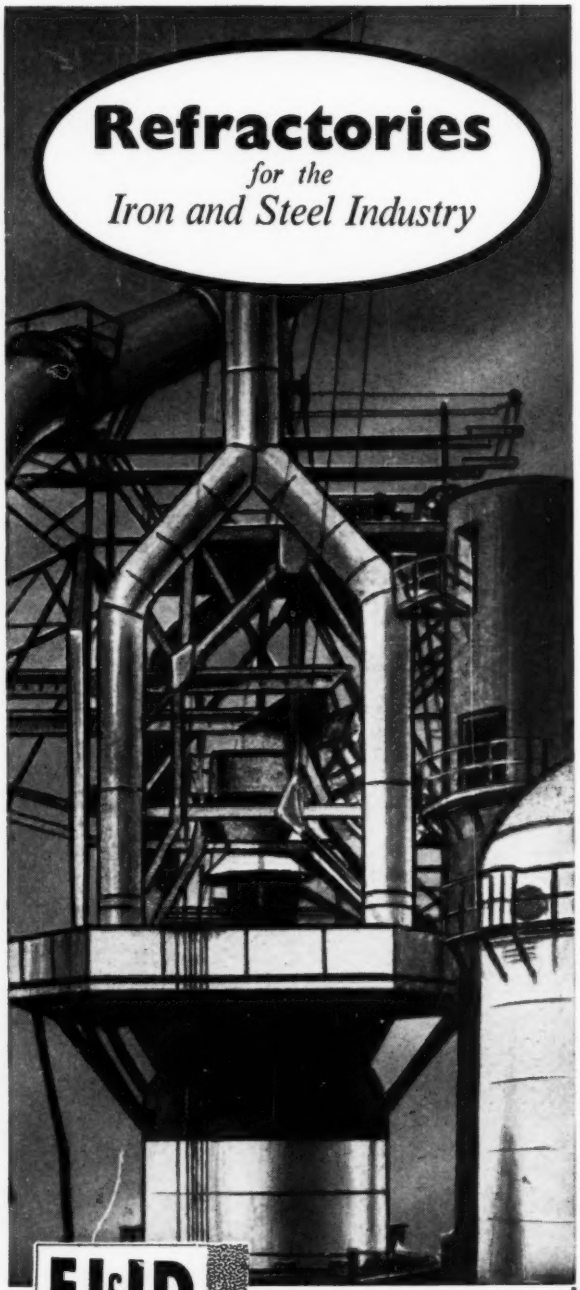

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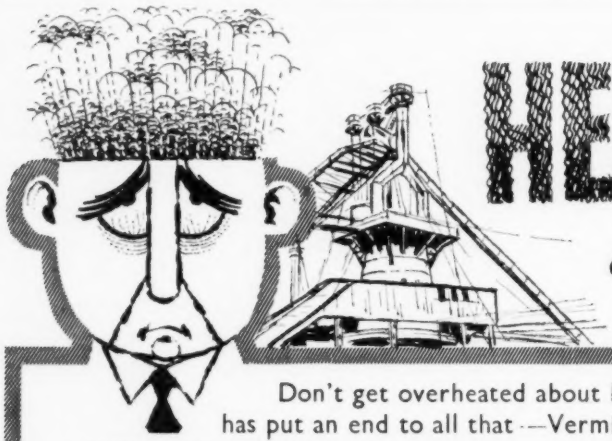

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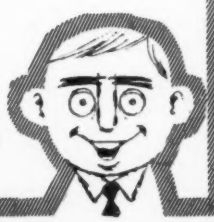

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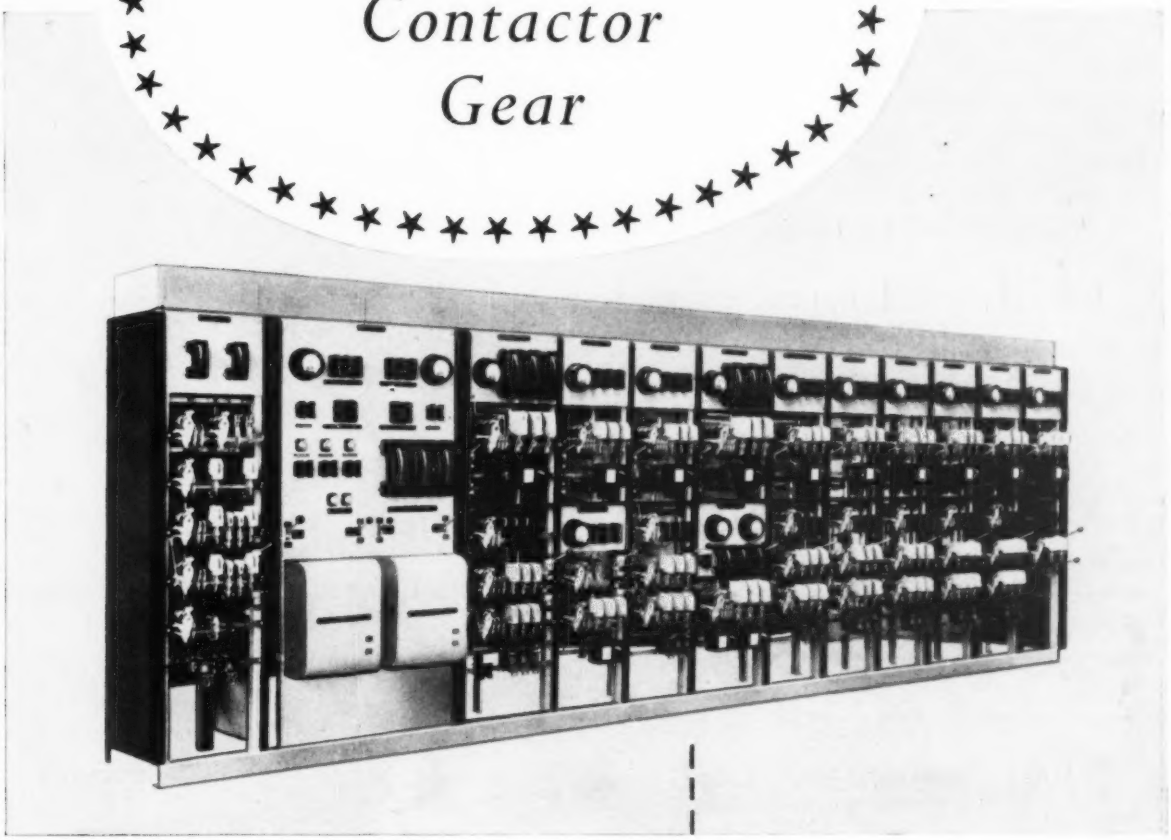

One of the many control boards together with control desks supplied to The Steel Company of Wales Limited for the Coiling, Cut up and Finishing Lines at their Abbey Works.

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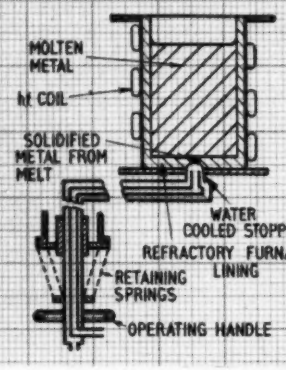
NO MIS-RUNNING



A water-cooled hemispherical copper stopper is positioned in the pouring orifice before the start of the melt. When melting begins, liquid metal is solidified immediately on contact with the stopper; the resulting plug of metal being kept solid by the water cooling supply to the stopper. Before pouring, the stopper is swung clear and the plug melted by conduction from the melt. The stopper can be replaced immediately after pouring since the sealing face remains clean and there are no mating faces to require regrinding. The crucible can thus be recharged quickly and safely without fear of misrunning.
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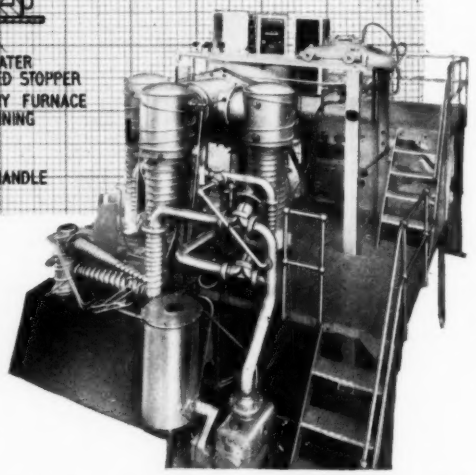

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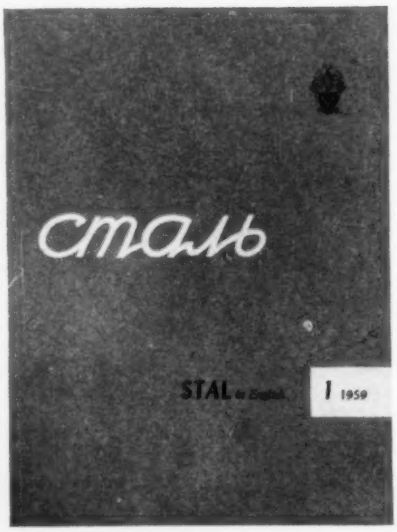

By arrangement with the Department of Scientific and Industrial Research, The Iron and Steel Institute is now publishing monthly a complete English-language version of STAL (*Steel*), the major Russian periodical in the field of iron and steelmaking technology. The developments reported in *Stal in English* are of the greatest interest to everyone connected with iron and steelmaking.

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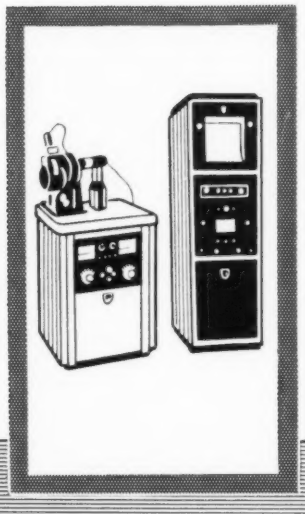

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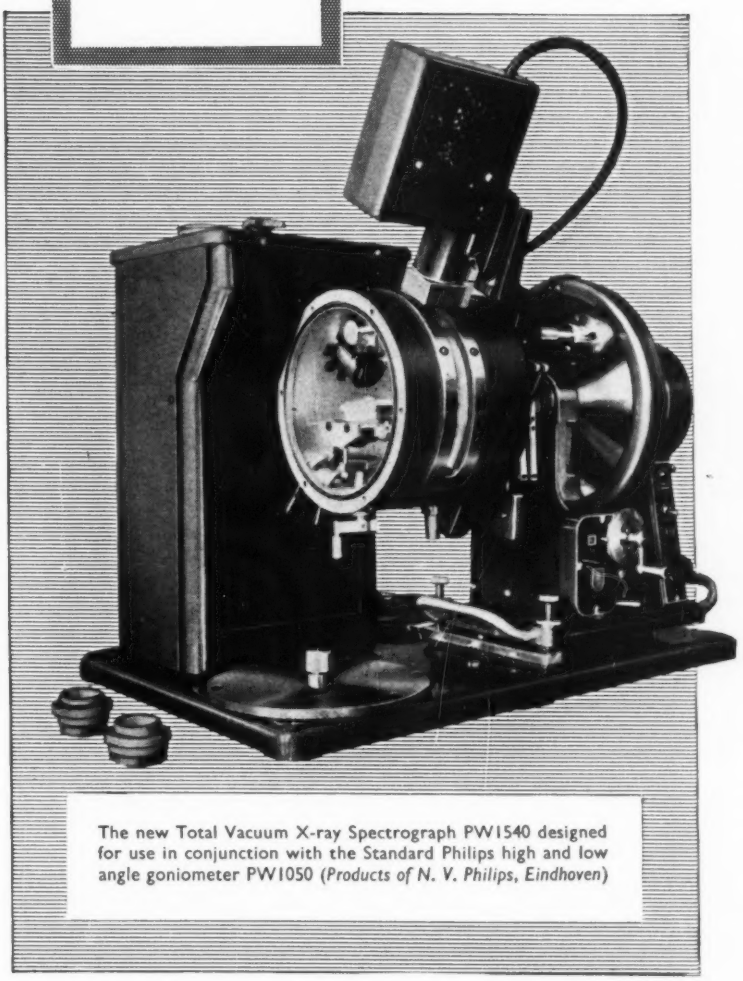

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Special Report No. 66

Sixth Report of the Corrosion Committee

The corrosion of iron and steel costs industry millions of pounds every year, and research on the best ways of saving this money is of the highest importance. The Sixth Report of the Corrosion Committee, which was founded in 1928, has recently appeared as No. 66 in the Institute's Special Report series; it contains an account of the researches carried out during the past twenty years.

The Report covers the corrosion of iron and steel in air, in soil, and in water; it details the results of numerous experiments and recommends methods of protection against the many different forms of corrosion. Reports of tests carried out to ascertain the corrosion rates of different kinds of bare irons and steels all over the world, and of steels protected with paint and/or metal coatings, are given.

Two other interesting researches described in the Report concern the corrosion and protection of steel at elevated temperatures up to 350°C, and marine corrosion. As a result of the latter, several reliable anti-corrosive compositions have been formulated, some of which are in use on H.M. ships and the "Queens".

The Report, which consists of 228 octavo pages, illustrated with 20 line and 21 half-tone figures, and bound in cloth with stiff board covers, costs £3 3*s*. 0*d*. (postage 1*s*. 0*d*.), and may be obtained from:

The Secretary, The Iron and Steel Institute,
4 Grosvenor Gardens, London S.W.1

Electrical Aids in Industry — *Data Sheet* **No. 8**

Light-Sensitive Cells

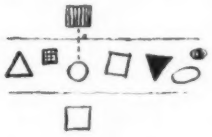
What are light-sensitive cells? They are devices which can sense and measure changes in the level of light or, in some cases, respond to the quality of light falling on them. There are various types of cell and each has its particular field of use. One of the best known is the photo-electric cell.

What can light-sensitive cells do? A change in the amount of light falling on the cell can cause a switch, relay or counter to operate. Alternatively, the direct indication of the light intensity can often allow some other factor to be determined and, if required, controlled. They are reliable and require little maintenance. Careful installation, as with all types of equipment, gives a good reward.

How can they be used? These cells have many applications in industry, for controlling processes, for inspection and measurement, for sorting material and for safety purposes:

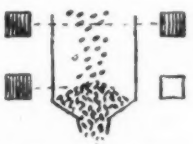
Counting

Where objects on a conveyor belt are too soft or light to operate a direct mechanical counting device, where they are too delicate or freshly painted to sustain physical contact or where the articles vary in size, a light-sensitive cell can be used. This counts the objects by interruption of an appropriately sited beam of light.



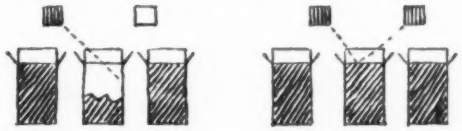
Hopper or Tank Level Control

Many forms of feed can be accurately controlled by light cells. One important one is for controlling the input to a hopper of fluid solids such as sand or peas. Here, two horizontal light beams are required: the upper, when interrupted, indicates that the hopper is full and stops the supply; the lower, when it ceases to be interrupted, indicates that the hopper is nearly empty and restarts the flow.



Package Content

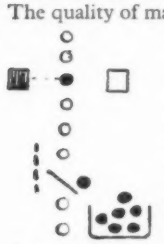
The level of powder in packages can be checked with light cells. The cell is so positioned that when the



powder is up to the required level, the light reflected from the surface of the powder is picked up by the cell and causes the carton to be accepted. If not, it is rejected.

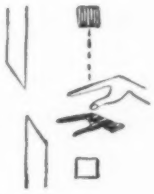
Colour Sorting

The quality of many articles can be gauged by their colour—seeds and nut kernels, for instance. The objects are fed into a tube by means of a vibrator pan and fall into the beams of three equally spaced light cells which scan them from all sides. If the object is acceptable it falls into a chute carrying it to one conveyor; if its colour is bad it is deflected as a reject.



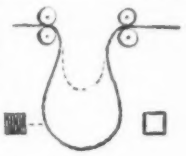
Guillotine Guard

Light cells for guarding a guillotine or power press should be used only as a supplement to a mechanical guard or where the latter is impracticable. The interruption of a curtain of light by a hand stops the machine instantaneously.



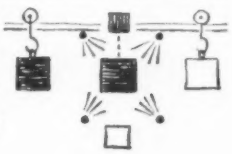
Press Feeding

Where the rate of feed of strip metal must be suited to a varying speed of acceptance by a press, a loop of the strip is allowed to sag between the feed and the press. When the loop reaches a predetermined depth a light beam is interrupted and the slack is taken up.



Processing Objects on the Move

Many articles are processed while on a conveyor line. For instance, where articles are to be sprayed while on the conveyor, the paint saved by stopping the gun between articles will make the device worthwhile. The same principle applies in a bakery to the spraying of baking tins with fat.



Automatic Door Opening and Closing

Doors can be caused to open or close by the interruption of a beam of light. This has its uses in such cases as control of doors on a heating oven or for the passage of vehicles in a factory. This is effected by a light beam on the side from which the approach is made (in many cases, both). When the approach beam is interrupted it opens the door which closes again after a given time interval.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association.

An excellent series of reference books are available (8/6 or 9/- post free) on electricity and productivity — "Higher Productivity" is an example. E.D.A. also have available on free loan a series of films on the industrial uses of electricity. Ask for a catalogue.

Issued by the Electrical Development Association
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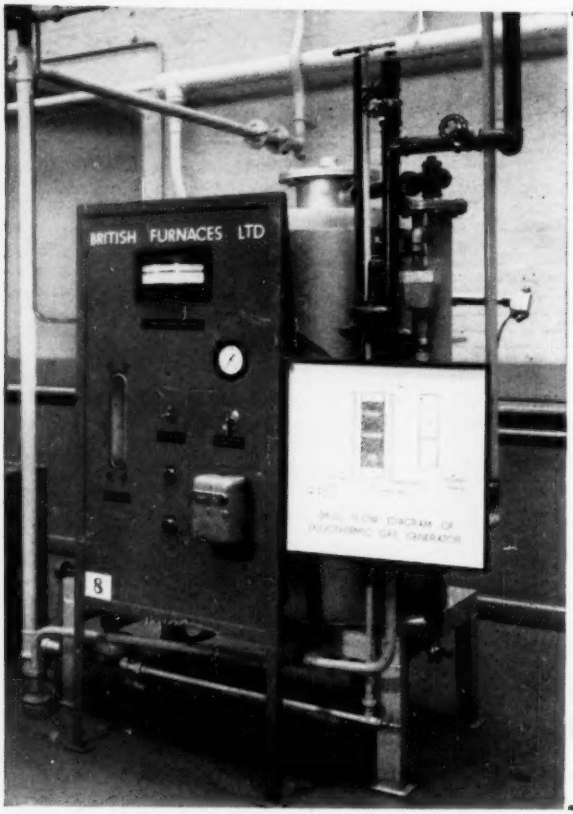

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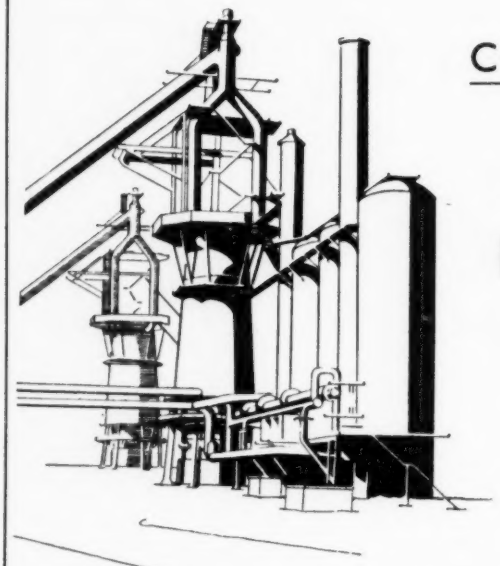

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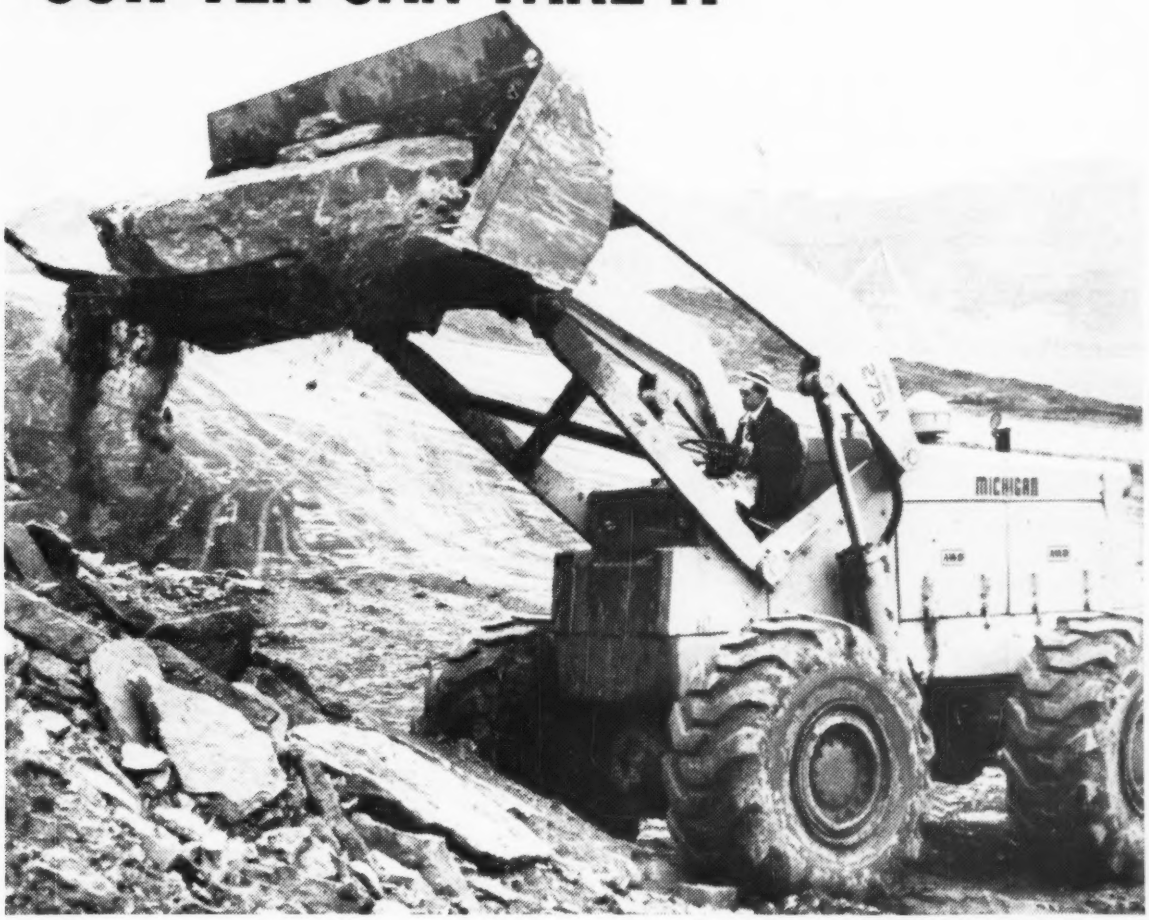

Super-tractor shovel shifting rocky overburden (Photograph by courtesy of Michigan (Great Britain) Limited)

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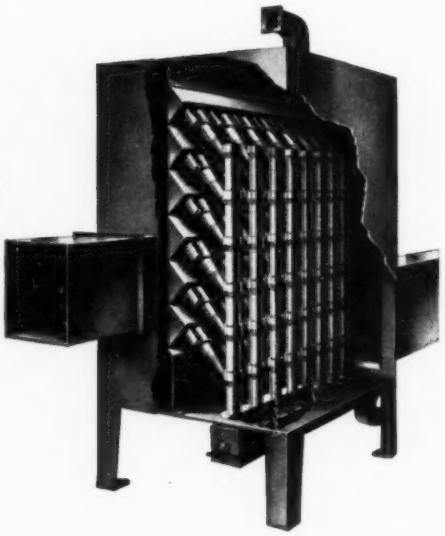

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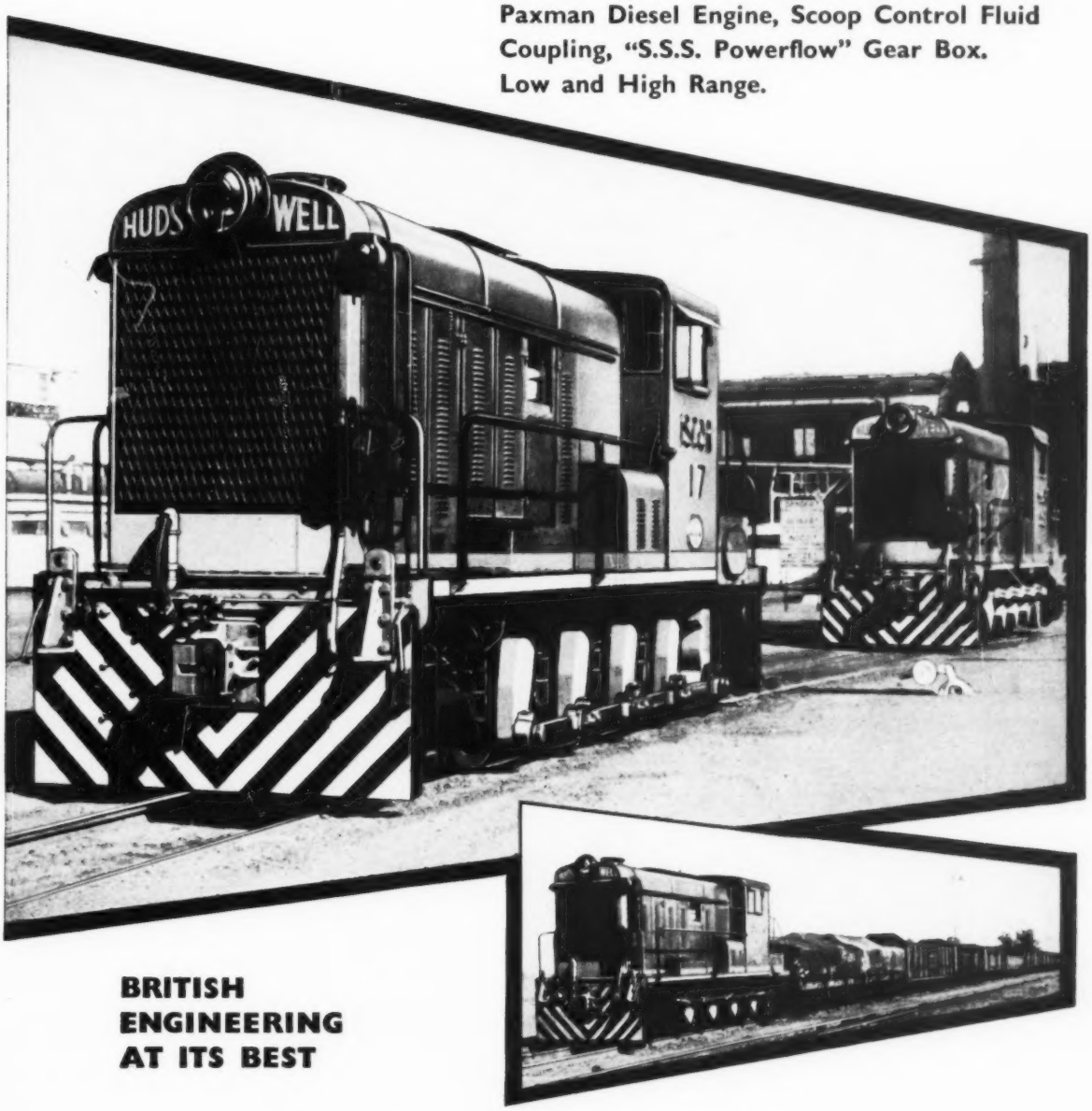

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2,000 TONS PER DAY

Nº 4 BLAST FURNACE.
WEEKLY PRODUCTION

WEEK ENDING	GRADE	OUTPUT	CONSUMPTION FIGURES LBS PER TON PIG IRON								BLAST TEMP.
			ORE LBS.	LIMESTONE	IRON ORE NUTS	SINTER	COKE BREEZE	DUST OR FLUE DUST	METALLIC IRON		
5/9/59	BASIC	12350	44194	9	3171	1689	68	1757	174	63.0	1557
12/9/59	"	13110	42814	240	1678	1698	68	1746	177	60.7	1376
19/9/59	"	13610	44246	234	1679	1698	68	1747	169	60.3	1396
26/9/59	"	12490	44268	289	1620	1696	66	1696	121	62.88	1399
3/10/59	"	13780	44173	288	1666	1698	67	1733	127	61.85	1394
10/10/59	"	14160	42754	339	1619	1698	69	1688	84	60.35	1446

RECORD PRODUCTION.

DAILY	DATE	WEEKLY	DATE	MONTHLY	DATE
2240	28/9/59	14160	10/10/59	55883	31/8/59

Nº 4 BLAST FURNACE
DAILY PRODUCTION.

DATE	GRADE	OUTPUT	AVERAGE ORE BURDEN	VOLUME BLOWN	ZONE NOTICE	DUST LOST	REGULARITY OF WORKING
4/10	BASIC	2130	4352	102000	100RD	70	REGULAR
5/10	"	2000	4353	102000	100RD	62	STOP 1'3" IRREG 2'23"
6/10	"	2070	4360	100916	100RD	139	IRREG 3'-0"
7/10	"	2050	4309	101164	100RD	71	REGULAR
8/10	"	2050	4229	101680	100RD	64	REGULAR
9/10	"	1950	4206	101080	100RD	78	STOP 25"
10/10	"	1910	4163	101872	100RD	119	STOP 20" IRREG 12'20"
OUTPUT WEEK ENDING 10/10/59				14160			TONS
TOTAL PROD. THIS MONTH TO DATE				20000			TONS
AVERAGE OUTPUT PER DAY THIS MONTH				2000			TONS

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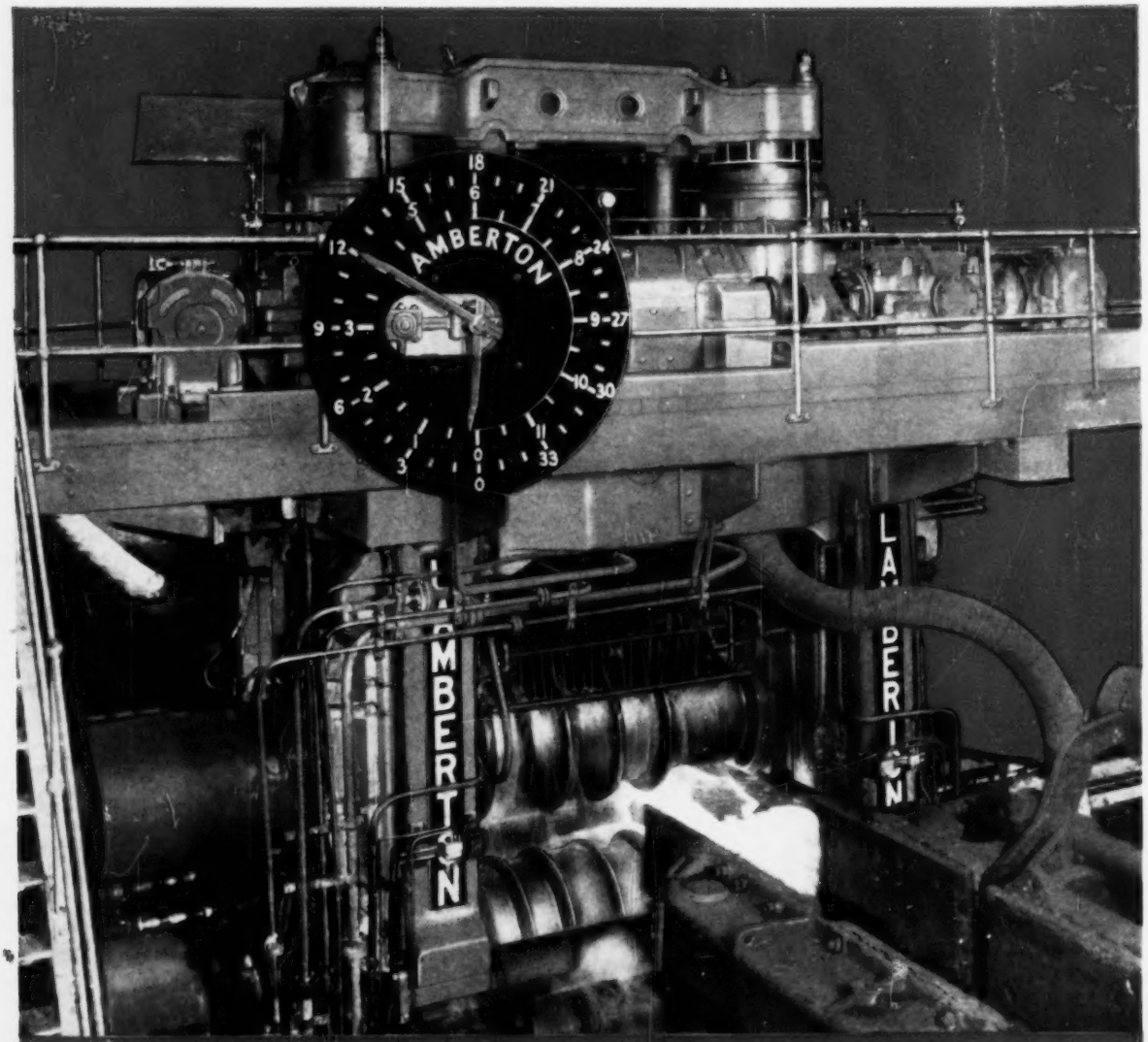

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